NCCARF
National
Climate Change Adaptation
Research Facility

Synthesis and Integrative Research
Final report

# Supporting evidence-based adaptation decision-making in Queensland: a synthesis of climate change adaptation research

AECOM

# SUPPORTING EVIDENCE-BASED ADAPTATION DECISION-MAKING IN QUEENSLAND

## A synthesis of climate change adaptation research


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The role of NCCARF is to lead the research community in a national interdisciplinary effort to generate the information needed by decision-makers in government, business and in vulnerable sectors and communities to manage the risk of climate change impacts.

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# Shortened forms

| | |
|---|---|
| **ACT** | Australian Capital Territory |
| **AEP** | Annual Exceedance Probability |
| **BCA** | Building Code of Australia |
| **BoM** | Bureau of Meteorology |
| **CALD** | Culturally and Linguistically Diverse |
| **CSIRO** | Commonwealth Scientific and Industrial Research Organisation |
| **CSO** | Community Service Organisation |
| **DCC** | Department of Climate Change |
| **DCCEE** | Australian Department of Climate Change and Energy Efficiency |
| **DECCW** | NSW Department of Environment, Climate Change and Water |
| **DEFRA** | United Kingdom Department for Environment, Food and Rural Affairs |
| **DERM** | Queensland Department of Environment and Resource Management |
| **DoHA** | Australian Department of Health and Ageing |
| **FORNSAT** | Forum for NCCARF interaction with states and territories |
| **GIS** | Geographical Information System |
| **ILM** | Integrated Land Management |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **ISO** | International Organization for Standardization |
| **NCCARF** | National Climate Change Adaptation Research Facility |
| **NDRRA** | Natural Disaster Recovery Relief Arrangements |
| **NGO** | Non-governmental Organisation |
| **NSW** | New South Wales |
| **NT** | Northern Territory |
| **OEH** | Office of Environment and Heritage |
| **PCF** | Policy Choice Framework |
| **QFCI** | Queensland Floods Commission of Inquiry |
| **QFF** | Queensland Farmers' Federation |
| **Qld** | Queensland |
| **QUT** | Queensland University of Technology |
| **SA** | South Australia |
| **SAFECOM** | South Australian Fire and Emergency Services Commission |
| **SCRGSP** | Steering Committee for the Review of Government Service Provision |
| **SME** | Small or Medium Enterprise |
| **VCAT** | Victorian Civil and Administrative Tribunal |
| **VIC** | Victoria |
| **WA** | Western Australia |

# EXECUTIVE SUMMARY

## Project background

A growing recognition of inevitable global climate change has led to significant research investment aimed at understanding the impacts of climate change and how to best adapt to these changes. As part of this, the Australian Government established the National Climate Change Adaptation Research Facility (NCCARF) in 2008 to harness Australian research capabilities to support adaptation decision-making.

In 2012, NCCARF commissioned this project, a synthesis of the research for each Australian state and territory, to answer a fundamental question: "What are the common emerging adaptation research lessons that can be used by state and territory decision-makers, particularly with regards to policy-setting?"

### *What is adaptation?*

This project utilises the Intergovernmental Panel on Climate Change (IPCC) definition of adaptation to determine research for inclusion in this synthesis. The IPCC defines adaptation as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC WG2

This report for Queensland is one of seven reports produced by AECOM for this project. A report was created for each state and territory with the exception of Tasmania. A Tasmanian report was produced separately by the University of Tasmania.

### Current and future climate in Queensland

- Temperatures in Queensland have been increasing, with data over the last century showing the State's rate of increase as being above the global average. This is predicted to continue, with inland regions expected to experience the greatest increase.
- Heavy rainfall events are a common and natural part of the State's climate; however, the intensity of these events has recently been above average, resulting in severe flooding. Long-term average annual rainfall is decreasing, and this is predicted to continue.
- Tropical cyclones pose a significant threat to north Queensland. Future climate models show a decrease in the number of cyclones, but an increase in the intensity of those that do occur.
- Sea level rise varies regionally, but is predicted to continue to increase at a rate above the global average.

### Climate change impacts

- Potential health and wellbeing impacts of heatwaves, cyclones, floods and other extreme events include injury, interruption to vital services and spread of vector-borne disease.
- Primary production is expected to be impacted by reduced rainfall, increased temperatures and physical damage to assets and infrastructure. This includes a potentially significant drop in productivity of the state's beef industry due to cattle heat stress.
- Climate change presents an additional threat to the large number of ecosystems already identified as threatened or vulnerable in Queensland. The natural environment will also be affected by bushfire, sea level rise and cyclones.

## State government's role in adaptation

The purpose of this project is to synthesise adaptation lessons relevant to decision-makers in state and territory government. State and territory government has an essential role to play in supporting adaptation to climate change. States have direct involvement in managing a range of assets and government services, and as a result have a significant role in direct adaptation actions. This has been exemplified by the Queensland Government response to the floods of January 2013, which is focused on building resilience into communities and infrastructure.

States also play a role in creating an institutional, market and regulatory environment that supports and promotes adaptation to climate change. The Queensland Government has taken steps in this regard, including the changes to planning and development processes to require the consideration of adaptation (Gurran et al. 2011). The recently released Draft state planning policies and State planning regulatory provisions both include planning and development policies aimed at reducing the risks associated with natural hazards. In February 2013, Queensland also amended the *Queensland Reconstruction Authority Act 2011* in order to effectively recover from disaster events and to improve community resilience. Further discussion of Queensland's adaptation activities can be found in Section 2.3 of this report.

## Research collected for synthesis

The project has drawn on a broad range of published research, including draft NCCARF research reports not yet publicly available. The majority of research utilised for the synthesis was funded by NCCARF. However, over 450 research reports were gathered in total from Australian journals and publications and included in the database that accompanies this project. Up to 15 pieces of research specific to each state but not part of the NCCARF-funded research pool were selected and reviewed for synthesis in addition to the NCCARF reports. This research was selected based on its relevance to state government policy.

The figure below maps the study locations and regions within Queensland examined in the synthesised research. It shows that research has been concentrated along the coast, particularly in and around Cairns and Brisbane. Case study locations were often chosen because they had previously experienced extreme events, such as floods. Regions examined include the Bowen Basin, Lockyer Valley and South East Queensland.

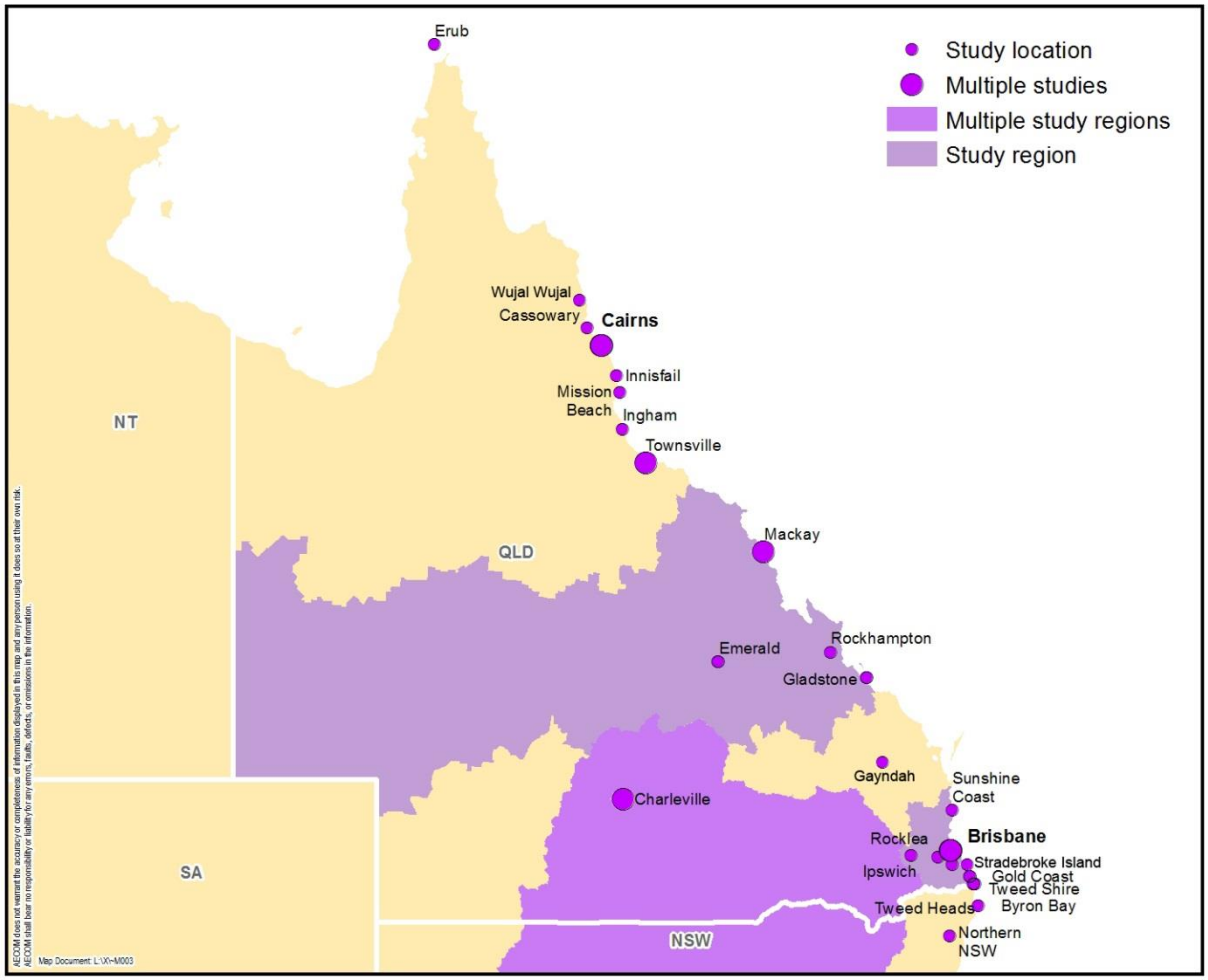



**Figure ES: Case study locations of Queensland research**

## Synthesis of findings by theme

The role of a synthesis is to value add to existing research by breaking down individual research reports and aggregating findings to form a new whole based on common threads or themes of learning. The main themes utilised in this synthesis are increasing resilience and adaptive capacity; learning from experience; costing, financing and funding adaptation; limits and barriers to adaptation; maladaptation; and the timing and scale of adaptation. It should also be noted that, due to the nature of the research reviewed, this synthesis largely presents broader findings rarely specific to an individual state/territory. The primary research findings are summarised below under these key themes.

### Increasing resilience and adaptive capacity

Adaptation actions are largely centred on increasing a community's or system's adaptive capacity and resilience and thereby reducing its vulnerability. However, as the research indicates, determining an effective method by which to increase resilience can be challenging.

Adaptation responses and emergency assistance need to take into account a community's short- and long-term challenges, including broader socio-economic issues, as well as ensure preparedness is holistic and tested for robustness (Black et al. 2013D[1]; Boon et al. 2012D; Sherval and Askew 2012; Kiem et al. 2010a). At the community level, government disaster assistance can deter residents from securing insurance and can in some instances facilitate departure from a community post-disaster (Boon et al. 2012D). Limited assistance from government or insurers for pre-disaster preparation has been trialled. It is also important to remember that some

[1] Note that references ending in capital 'D' are draft NCCARF research reports; the date shows the year they were made available for incorporation into this synthesis report.

communities are inherently more vulnerable than others and that community and system vulnerability may change over time (Hanson-Easey et al. 2013D; Boulter 2012; Kiem et al. 2010a).

Community connectedness and the presence of local networks were found to be strong contributors to community resilience and recovery (Boon et al. 2012D). State government can help guide local efforts and initiatives and support local government and community service organisations in their efforts to assist communities (Mallon et al. 2013D; Boon et al. 2012D). A useful starting place for collaboration for adaptation is disaster risk management, as these arrangements are historically and currently formed around interagency and intergovernmental approaches (Howes et al. 2013D).

Building resilience and adaptive capacity also relies on the need to better consider messaging and communication. Engagement can help increase community preparedness, create ownership of and buy-in for adaptation options, improve social cohesion, and can increase confidence in governance processes. Clearly articulating adaptation goals (together with options) and using shared terminology are seen as key to engaging the community (Howes et al. 2013D; Johnston et al. 2013D; Hadwen et al. 2011; Kiem et al. 2010b). In addition, it is important to use bespoke, tailored messaging to reach intended audiences and to distribute information through multiple, diverse channels (Boon et al. 2012D, Hanson-Easey et al. 2013D, Reser et al. 2012).

For natural systems, current efforts to improve habitat protection are considered the optimal action for assisting the majority of species adapt to climate change within the budgetary limitations. However policy and management needs to transition to ecosystem-based approaches that seek to maintain function.

In primary production systems, adaptation will largely be driven by the private sector; however, government still has a key role to play in helping set the right policy conditions and through the provision of appropriate incentives. Implementation of market-based instruments, such as water trading, needs to better consider broader social and economic impacts, including the capacity of participants to engage in change.

**Learning from experience**

Adaptation planning will be informed by lessons learned from past events. Recent events (drought, bushfire, floods and storms) have resulted in various policy responses across the country, enabling rapid mobilisation of resources across all levels of government (Howes et al. 2013D). However, prior experience with natural disasters can be unpredictable in its influence on community resilience. Communities with a collective memory of a crisis may be able to respond with adaptive change more easily than those with lack of experience; however, despite past experience, many communities still do not take steps to prepare for the next event (King et al. 2012D; Kiem et al. 2010a). Preparedness for one disaster, such as drought, can also make residents and agencies less concerned or prepared for other potential risks, such as floods (Bird et al. 2011; QUT 2010).

Basing decisions on past experiences will become increasingly risky. There is a tendency to stay within known parameters and uncertainties, yet there is a growing need to understand system-wide properties at scales and within timeframes beyond the normal comfort zone of most decision-makers (Albrecht et al. 2010). Furthermore, because of the urgency to re-build quickly, adaptation measures implemented after extreme events may not take adaptation opportunities into account or be fit for purpose with continued climate change and may increase vulnerability in the longer term (Albrecht et al. 2010; Kiem et al. 2010a).

Extreme events can also provide an impetus for overdue and unpopular adaptation actions (Kiem et al. 2010a) and can enable governments to mandate change, making implementation of actions progressively more affordable (Mason and Haynes 2010). However, the opposite can also be true. For some disasters, attitudinal barriers, such as the common belief that excessive heat is not a threat in a warm country, can prohibit planning and action. Public education campaigns are recommended (QUT 2010).

**Costing, financing and funding adaptation**

Adaptation options entail varying costs, both in terms of time and resources involved in their implementation and maintenance as well as with respect to the risks involved (Hadwen et al. 2011). Robust costing must take into account a wide range of direct and indirect impacts of both climate change itself and the responses put in place. The effectiveness of some options may decrease as climate change continues or as other factors modify the impacts. The return on adaptation needs to be considered beyond the short term and in relation to the distribution of costs and benefits to the broader community.

Disaster relief funding is considered by some to be over-generous and untargeted, and its ability to increase resilience to disaster under current arrangements is questioned (Wenger et al. 2012D). It also frequently does not provide assistance that takes into consideration a local government's capacity to commence emergency works or the longer-term cost impacts of the extreme event (Verdon-Kidd et al. 2010).

Consideration of who pays for adaptation is also an ongoing issue for many decision-makers. Economic tools that estimate specific costs and potential benefits throughout the community can help inform sensible choices about which adaptations, or suite of adaptations, are likely to yield more benefits than they cost to implement (Fletcher et al. 2013D). Currently there is limited research testing how adaptation costs and benefits might be distributed through the community.

Insurance is generally considered an important adaptation tool to help defer climate change risks, particularly in the private sector. However, there are limitations associated with insurance arrangements, individual behaviours and government responses to natural disasters. There is also limited practice by insurers to promote or encourage actions that reduce or avoid future risks associated with climate change (Bird et al. 2011). Ultimately, in the case of a disaster when people are not insured, it is the government that bears the risk.

Apart from water trading, there are few tested market-based mechanisms for adaptation. Market-based approaches to adaptation are particularly important to encourage financing of physical assets and infrastructure.

**Limits and barriers to adaptation**

Understanding the limits and potential barriers to adaptation can help decision-makers determine more practical and legitimate responses to climate change and better engage with stakeholders (Morrison and Pickering 2011). The primary limitations identified in the research are as follows:

- *Lack of community support.* Public opposition and poor communication with stakeholders can derail adaptation implementation (Poloczanska et al. 2012; Haynes et al. 2011; Petheram et al. 2010). Varying perceptions of adaptation interventions among stakeholders can also be a major source of conflict (Evans et al. 2011; Gross et al. 2011).
- *Current institutional and legislative frameworks.* Practical management strategies at the local or state level can be constrained by higher level government legislation, which may not take into account local conditions (Robson et al. 2013D; Hadwen et al. 2011). Institutional arrangements can also create barriers for effective collaboration, such as the relatively little transfer of expert personnel between the planning, building and insurance professions (King et al. 2012D).
- *Capacity and resource constraints.* Resource and capacity constraints can relate to financial or human capital limitations. Local governments, in particular, find long-term, large adaptation projects are beyond their capabilities (Mukheibir et al. 2012). There is also often an issue of split incentives, where the person able to fund an adaptation intervention is not the one who benefits in terms of avoided costs.
- *Lack of system understanding.* Unknown thresholds of ecological resilience and lack of understanding about the interconnectivity within ecosystems limit the identification of effective adaptation options (Hadwen et al. 2011).
- *Lack of accessibility to up-to-date and relevant information.* There is a distinct lack of coordination of existing databases and data-sharing arrangements between relevant authorities (Hadwen et al. 2011).

**Maladaptation**

Adaptation-related decisions intended to reduce climate change impacts may instead increase vulnerability. This problem of increasing risks from adaptation is often termed ‘maladaptation’. Maladaptation can occur when the connections and interdependencies of systems are underestimated, particularly in the context of natural ecosystems (Hadwen et al. 2011). Therefore, it is critical to the success of adaptation activities that the connectivity between ecosystem and human systems is considered within the decision-making process. A number of climate change adaptation and mitigation policies also have the potential to negatively affect the most vulnerable sectors of society due to the inequitable distribution of economic impacts (Mallon et al. 2013D).

**Timing and scale of adaptation**

The timing for and scale at which adaptation is best delivered remain fundamental questions. Adaptation will continue to be a series of reactions to environmental and social changes – some quickly executed in response to emergencies, others more autonomously in response to slowly changing social and economic conditions (Gross et al. 2011).

Government and communities have tended to favour short-term and responsive approaches; this can make adaptation more difficult to initiate and more expensive (Stanley et al. 2013D). Adaptation actions need to take a long-term view to be effective (Hadwen et al. 2011). Having more flexible and dynamic policy and planning that looks beyond political cycles is needed for this forward-thinking approach.

At the same time, the windows for adaptation opportunity following extreme events are relatively short, largely due to current funding arrangements and community expectations. Rapid recovery may hinder adaptation, as new knowledge can take time to incorporate into existing regulations and guidelines (e.g. revised building codes). However, there is a need to act quickly, while the issue remains within community memory and before complacency sets in (Helman et al. 2010).

Triggers need to be considered for extreme events. At the same time, the increasing frequency of climate-related events is changing the perception of what is an extreme and what is 'normal climate' (Kiem et al. 2010a). In light of this, disaster management arrangements need to be reviewed. This is typified by changes in drought policy responses in Australia over the past 20 years.

Finally, it is important to recognise that doing nothing may be an appropriate adaptation response if and only if (Garnett et al. 2012D):

- full consideration of the potential consequences has been given
- there is ongoing monitoring of climate change risks
- there is flexibility to recognise and respond to changed circumstances in a timely manner.

## Synthesis of findings by sector

A primary purpose of this synthesis was to look across sectors and to integrate and aggregate findings into common threads or themes of learning. This is particularly important in adaptation as responding to climate change largely requires a holistic, systems approach to avoid maladaptation and to manage risks (including non-climatic threats) over the long term. However, this report also contains lessons relevant to specific sectors, particularly for natural resource management, primary production and land use planning, and a list of practical adaptation responses has been suggested from the research. Sectors covered under practical actions include coasts, land and water management, the built environment, emergency management, and communities. However, it is also important to note that in no way did the research reviewed comprehensively cover any individual sector. The table below provides a summary of the key findings for each sector.

### Table ES: Findings for Queensland by sector

| | |
|---|---|
|  | Key findings related to adaptation and natural resource management:<br>- Existing management strategies will lessen the impacts on ecosystems, but the objectives of conservation and management plans will need to be reconsidered in the context of longer-term climate change.<br>- Habitat protection is currently considered the optimal action for assisting most species adapt to climate change within budgetary limitations. However, adaptation also needs to take an ecosystem-based approach where resources are directed towards a suite of actions. Effective adaptation requires adaptive management, meaning actively experimenting with actions and learning from past activities.<br>- There are conflicting conclusions regarding whether water pricing reduces water use. |

| | |
|---|---|
|  | Key findings related to agriculture, fisheries and forestry:<br>- Diversification is the effective strategy for mitigating climate-induced variability.<br>- Not all producers will be able to participate in water trading. Cost of water may affect the long-term viability of some sectors of south-east Queensland's agricultural industry.<br>- Adaptation will be primarily driven by private sector responses, but government needs to play a supporting role to ensure the effectiveness of adaptation responses.<br>- Individual farms have coped with periodic events through a range of management and behavioural changes. The effectiveness of these options in the long term needs to be considered, as does how to transition agricultural production from areas of high vulnerability to low vulnerability to maintain food security. |
|  | Key findings related to infrastructure, communities and land use planning:<br>- There are issues of continued expansion of populations into at-risk areas, particularly with regard to coastal inundation and cyclone risks.<br>- Regulatory instruments in land use planning need to have a precautionary approach, including greater flexibility to support adaptation.<br>- Through development regulation, land use planning can play an essential role in reducing climate risks to populations and infrastructure. This will be critical in the various rapid growth regions of Queensland.<br>- Indigenous communities, particularly in remote areas, are often the most vulnerable to climate change. However, remoteness can also increase resilience and adaptive capacity, particularly when a strong connection to country is maintained.<br>- Climate change adaptation programs targeted to Indigenous communities should focus on empowering communities to identify and implement their own responses. |
|  | Key findings related to health and wellbeing:<br>- There is need for a consistent heatwave policy for the management of aged care facilities.<br>- State government should ensure adequate health services are available, both during and for the longer term after disaster events.<br>- Targeted adaptation messages need to be developed for specific audiences, including communities in the Torres Strait. |
|  | Key findings related to business and industry:<br>- Adaptation action within small and medium businesses may be resource constrained.<br>- There is limited Australian research available in relation to potential adaptation responses for mining operations and the tourism sector. |

## Conclusions

The complexity of climate change adaptation cannot be underestimated. A wide range of issues, including national and state policy contexts, local institutional constraints, short- and long-term climate variability, local community needs and environmental conditions play a role. As pointed out by Gross et al. (2011) "adaptation to climate change should be considered as one aspect in a complex, ever changing set of environmental, social and economic circumstances" (p. 77).

There are also clear challenges associated with the scale of adaptation required, the timing of when to introduce interventions and how interventions are best delivered. Improvements in climate change science can only

partially reduce this uncertainty and adaptation planning must accept this fact. These uncertainties highlight the need for flexibility, both as new information emerges and as society evolves.

Climate change uncertainties are not the only constraints, however. Changes within society and the environment – both in response to climate change and other forces and their influence on adaptive capacity and vulnerability – remain some of the greatest limits to effective adaptation. From these changes, values and priorities will also adjust and will need to be captured in adaptation objectives and actions.

Responses to recent extreme events have been examined to identify potential adaptation lessons, particularly with regards to floods, bushfires and drought. While it is critical that we learn from and address the many issues that arise from these events, the potential influence of further climate change has not been considered in order to identify where responses beyond 'business as usual' may be necessary. Further opportunities are lost by the rush to restore communities and meet shorter-term needs. The question of whether experience with disaster events improves community resilience also remains inconclusively answered – it appears that it depends on a range of factors, unique to each location, each event and each point in time.

However, experience from extreme events also brings hope. Stories of autonomous self-organisation and neighbourhood support highlight the need to continue efforts that strengthen a sense of community and ultimately improve adaptive capacity. Local knowledge provides considerable assets in the form of social capital and natural capital, demonstrating innovation in the face of adversity. Recognition and promotion of these behaviours needs to be considered and targeted in community support programs.

## Key lessons for state government decision-makers

***Monitor and evaluate existing adaptation practices for ongoing adaptation.*** Monitoring is essential to evaluate the effectiveness of current adaptation options, but it is also critical for continuous improvement, to build trust with stakeholders, and to effectively implement adaptive management.

***Increase effort in identifying adaptation opportunities and promoting positive change.*** While there is a need to continue to prioritise adaptation aimed at reducing the risk of harm and in evaluating the limits and barriers of adaptation, potential opportunities also need to be identified.

***Clearly define specific adaptation objectives.*** Decision-making, implementation and evaluation require an understanding of the government's appetite for risk and expected outcomes. Objectives also need to be defined in consultation with stakeholders.

***Ensure structures and institutions are flexible and can react to emerging issues and unforeseen events.*** From land use planning to natural resource management to primary production, there is need to ensure governance systems are flexible in order to respond to unforeseen events as well as incremental changes. Flexibility will also allow for continuous learning, which is essential for adaptive management.

***Continue efforts to build community cohesion.*** Building a sense of community is important to increase adaptive capacity and resilience and will have a range of benefits beyond climate change adaptation.

***Avoid calm weather planning.*** Taking a risk-based approach, which factors in both experience from past extreme events and future potential climate change, is a more robust approach for adaptation planning.

***Create opportunities for greater engagement with researchers.*** To take advantage of research and to support better adaptation planning, government decision-makers need early and frequent engagement with the research community.

# 1. INTRODUCTION

## 1.1 Project background

Over the past two decades, climate change activities by governments around the world have largely focused on reducing atmospheric greenhouse gas concentrations in an attempt to avoid dangerous climate change. However, a growing recognition of the inevitable impacts of climate change has led to significant research investment aimed at understanding the impacts of climate change and how to best adapt to these changes.

In response to climate change, the Australian Government established the National Climate Change Adaptation Research Facility (NCCARF) in 2008 to harness Australian research capabilities to support adaptation decision-making. The NCCARF program, together with research outcomes from other Australian research institutions, constitute an important part of the growing body of climate change adaptation knowledge for Australia's states and territories. Emerging from nine research plans for key sectors of Australian society, more than 100 research projects have been funded to support decision-makers in climate change adaptation.

NCCARF has commissioned a synthesis of research outputs to date for each Australian state and territory. The intent of this report is to inform policymakers and other interested parties of relevant research for Queensland (Qld) and identify what strategic implications and lessons can be learned from this research. At the same time, this synthesis is intended to identify transferable lessons between regions and sectors while also identifying emerging research gaps at both the state and national level. It also seeks to present findings and analysis in a way that will enhance adaptation understanding of decision-makers in state/territory government.

This report draws together and presents key findings and lessons from individual NCCARF research reports, and a selection of other supporting studies identified through a literature review. This report has been shaped by the needs identified by state and territory government representatives participating on NCCARF's forum for engagement with state and territory government, FORNSAT.

**Adapting to climate change**

This project uses the Intergovernmental Panel on Climate Change (IPCC) definition of adaptation to determine research for inclusion in this synthesis. The IPCC defines adaptation as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC WG2 2007). As such, the literature gathered and synthesised for this project is *not* focused on climate change science, climate change modelling, climate change risk or vulnerability assessments, although it is acknowledged that these often form a critical element of adaptation planning. It is focused on research that tests or discusses *responses* to climate change, that is, how natural or human systems can adjust to unavoidable climate impacts and the effectiveness of these adjustments in reducing vulnerability and adverse effects.

## 1.2 Report structure

This report consists of seven sections and four Appendices. Table 1 displays the main objectives and content of each section.

**Table 1: Objectives and content of report sections**

| Report section | Objectives | Content |
|---|---|---|
| 1.0 Introduction | To introduce the project background and purpose; to place the project in the context of the roles and challenges for state government. | Project background; scope and methodology; description of the role of government in adaptation; discussion of the adaptation challenge for government and research. |
| 2.0 Qld climate challenge | To describe the climatic challenge faced by Qld and Qld's existing adaptation priorities and actions. | Description of current and future climate conditions; key climate change impacts facing Qld; discussion of Qld's current adaptation priorities and activities. |
| 3.0 Research relevant to Qld | To provide an overview of the research collected for the synthesis and its geographical relevance. | Total number of research studies gathered; list and map of research reports with Qld-specific case studies. |
| 4.0 Research findings | To synthesise research reviewed based on common themes of learning for state government policy- and decision-making. | Key findings and supporting research by identified themes and sectors; also includes a list of practical adaptation options identified in the research. |
| 5.0 Policy and research engagement | To capture lessons regarding how the intersection of and interactions between policy and research may be improved. | Key findings from the research regarding improving researcher and decision-maker engagement; research gaps regarding the application of the research findings for specific end users. |
| 6.0 Conclusions | To summarise the fundamental challenges facing state government decision-makers and the key lessons. | Description of the adaptation challenges and potential policy implications; summary of identified lessons for decision-makers. |
| 7.0 Bibliography | To capture a full list of research reports reviewed for this project. | The bibliography includes all research reviewed for the synthesis, as well as cited research. Research reviewed but not cited also informed the thinking of this project. |
| Appendix A | Appendix A provides an overview of early consultation with FORNSAT representatives about their needs for this project. | |
| Appendix B | Appendix B provides a list of the nationally relevant NCCARF research projects. This list of projects does not contain case studies specific to an Australian state or territory. | |
| Appendix C | Appendix C provides summaries of all NCCARF-funded research that contains a case study within Qld. | |
| Appendix D | Appendix D provides a list of all NCCARF-funded research reports excluded from the synthesis and reason for exclusion. | |

| Icon key | |
|---|---|
|  | Natural environment |
|  | Agriculture, fisheries and forestry |
|  | Infrastructure and communities |
|  | Health and wellbeing |
|  | Business and industry |
|  | Emergency management |
|   | Government and governance |
|  | Tools |

**Sector icons**

Icons are presented throughout this document to represent the sectors or themes the information relates to, or to indicate whether it provides a tool or framework to assist the end user.

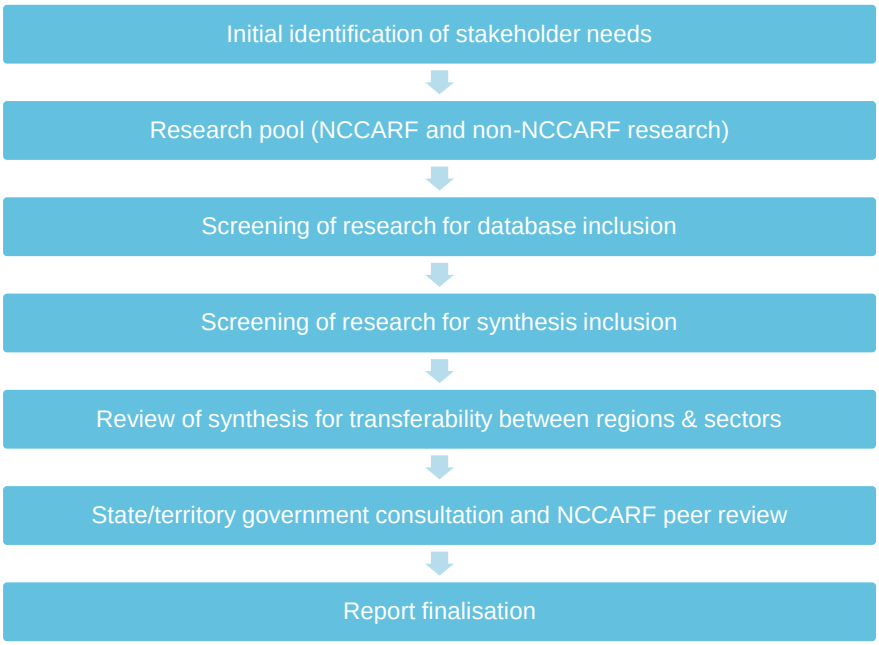
## 1.3 Scope and methodology

This project sought to identify relevant climate change adaptation research for each state and territory government while considering the transferability of research findings between jurisdictions. In addition to research commissioned by NCCARF, a scan of relevant scientific journals and Australian government websites was undertaken. The research reports collected during this scan are included in a database that accompanies this report, and a subset of this research is included in this synthesis report. The database is a searchable tool outlining NCCARF and non-NCCARF adaptation research in Australia.

The project has taken a broad view of published research: it has not been limited to peer reviewed literature, and it incorporates findings from NCCARF's draft research reports, some of which may not yet be in the public domain. The literature gathered and synthesised for this project is also *not* focused on climate change science, climate change modelling, climate change risk or vulnerability assessments, although it is acknowledged that these often form a critical element of adaptation planning. The research scan instead focused on research that tests or discusses *responses* to climate change, that is, how natural or human systems can adjust to unavoidable climate impacts and the effectiveness of these adjustments in reducing vulnerability and adverse effects. In addition, the report focuses on research that can inform directed and planned adaptation, particularly in relation to the roles and responsibilities of state and territory governments.

A summary of the methodology is outlined in Figure 1. Broader adaptation research occurring at other Australian locations is considered where it has been deemed that this research is relevant to Queensland. There is a growing body of international research which may also provide insights for adaptation planning and implementation in Queensland, but this information was beyond the scope of this project.

**Figure 1: Summary of project methodology**




***Initial identification of stakeholder needs***

At the beginning of this project, all FORNSAT representatives and, when requested, additional state/territory government employees were interviewed by phone to:

- better understand what they would most like to get out of this synthesis
- discuss identified or articulated priority climate change risks or adaptation priorities
- clarify where research has been used so far to inform policy and program development.

A summary of the interview results is included in Appendix A.

***Research pool (NCCARF and non-NCCARF research)***

This synthesis draws upon climate change adaptation research commissioned by NCCARF and research gathered through Australian sources. The primary sources for research gathered were:

1. Published and peer reviewed literature using relevant databases and key search terms.
    a. The databases utilised for the scan were Science Direct, APAIS, SciVerse Scopus, ANR index, ANR research, EVA, FAMILY, and CSIRO Publishing.
    b. Search terms included adaptation, adaptive capacity, climate change, climate impact, climate proofing, climate risk, climate variability, future proofing, resilience, and vulnerability.
2. Scan of State and Commonwealth websites for relevant research reports. Websites were scanned by entering the search terms into the search bar on State and Commonwealth department websites. The websites of Queensland Government departments searched include:
    - Department of Development, Infrastructure and Planning
    - Department of Transport and Main Roads
    - Department of Health
    - Department of Agriculture, Fisheries and Forestry
    - Department of Environment and Heritage Protection
    - Department of Natural Resources and Mines
    - Department of Energy and Water Supply
3. Engagement with FORNSAT representatives to nominate research. After the database search and website scan was complete, a full list of over 610 pieces of research was sent to each FORNSAT representative. FORNSAT representatives were then given two weeks to review the research relevant to their state/territory and provide feedback on inclusion or exclusion.

***Screening of research for database inclusion***

Prior to submitting the research list to FORNSAT representatives, AECOM assessed the research for inclusion in the project database that accompanies this report based on criteria agreed upon by FORNSAT representatives and NCCARF. This criteria list was also to be used by FORNSAT representatives to guide their research nomination process.

- primary research reports (mainstream media reports and peripheral research outputs were included)
- research published since 2001
- publicly available (confidential government reports or reports pending government approval were not included. An exception to this is NCCARF research.)
- consistency with the IPCC definition of adaptation
- of relevance/significant to the responsibilities and interests of Australian states and territories
- specifically considering responses to future climate change.

***Screening of research for synthesis inclusion***

All research reports included in the database were then considered for inclusion in the synthesis using the following criteria:

- relevance to state government roles and responsibilities
- ability to influence state government policy and decision-making
- robustness of research methodology to 'scale up' findings and lessons to sectors and regions
- provision of policy analysis or policy recommendations relevant to state and territory government roles and responsibilities.

The purpose of these criteria was to have the synthesis informed by research that is the most appropriate and relevant to a state and territory government audience.

The second purpose of these criteria and the inclusion/exclusion process was to allow AECOM capacity to review non-NCCARF research. Our initial scope of work allowed for a total of 150 reports to be reviewed for the synthesis. This was based on the synthesis being informed by NCCARF research only.

AECOM identified 454 non-NCCARF funded adaptation research articles that met the above four criteria. To consider all of these for the synthesis report in addition to the identified NCCARF research was beyond the scope of the project.

To resolve this issue, AECOM proposed that:

- all research that met the above four criteria were included in the database
- the synthesis was based predominately on findings from the identified NCCARF research but supplemented by the inclusion of up to 15 of the most relevant research papers for each state as identified by AECOM. NCCARF and FORNSAT were also invited to nominate research that they identified as being most relevant and influential.

Any NCCARF research reports provided to AECOM after close of business on 14 January 2013 were also unable to be included in the synthesis due to project time constraints.

***Review of synthesis for transferability between regions and sectors***

The research identified for each state/territory was initially reviewed and captured separately in order to draw out state/territory-specific lessons. However, as a stated interest from FORNSAT was identifying transferable lessons and comparisons across regions, states and sectors, the full body of research reviewed was considered for each synthesis report. As discussed under 1.3.1 Project limitations, there turned out to be limited consideration of geographical distinctions within the research examined, as only a limited number of research pieces considered the current policy frameworks for state government. As a result, the majority of research reports reviewed were determined to have elements of transferability between regions and/or sectors.

***State/territory government consultation and NCCARF peer review***

Draft reports were submitted to FORNSAT representatives and NCCARF in March 2013 for review. In March and April, AECOM also conducted a workshop in each state/territory (with the exception of the NT who were not interested in a workshop at this time) to further discuss the project and gather feedback. All workshop attendees

were also encouraged to thoroughly review the draft report for their state/territory and provide written feedback during the month-long review period.

Draft reports were also submitted for peer review by a qualified science reviewer identified by NCCARF.

***Report finalisation***

Feedback provided during consultation workshops along with written comments provided by FORNSAT representatives and NCCARF science reviewers were incorporated into the final versions of the reports. Each FORNSAT representative was also sent a draft version of their report with changes incorporated for a final review prior to submission to NCCARF for publishing.

### 1.3.1 Project limitations

The role of a synthesis is to value add to existing research by breaking down individual research reports and aggregating findings to form a new whole based on common threads or themes of learning. Within this approach, bias is inherent and the authors of this report acknowledge that bias. This bias was also inevitably further compounded by the interests and experiences of the individual authors of this report.

In compiling this synthesis, an interpretative approach was used and the research was approached subjectively – first to identify research findings relevant specifically to the responsibilities of state and territory, secondly to focus on research findings developed or currently being developed under NCCARF's program of research.

While this synthesis was also initially intended to draw out themes of learning specific to each individual state and territory, review of the literature indicated that:

- there is limited consideration of geographical distinctions within the research examined – largely as a result of only a limited number of research pieces giving consideration to current policy frameworks for this particular level of government
- research findings targeted to a location are often very specific and at a level of detail not necessarily relevant to a synthesis approach
- research findings were generally based on a specific climate hazard (such as flooding, heatwaves, bushfires, etc.), which are largely common risks faced by all states and territories but with different levels of likelihood and underlying vulnerability.

As a result, the roles and objectives of state government (when defined) are discussed to place the research in the context of each state/territory's needs and activities. However, this synthesis largely presents broader themes and findings occasionally specific to a sector but rarely specific to an individual state/territory. This can be considered an advantage as it creates a larger pool of potential knowledge, but it could also be a disadvantage as it presents few distinct and specific directions to further the adaptation policy creation and implementation at a geographical scale.

The synthesis and project database are also not intended to be comprehensive collections of all research on adaptation relevant to states/territories in Australia. As a result, the following limitations should also be noted:

- international adaptation research was not included unless it was specific to Australia.
- journal articles relating to climate change impact studies were not included unless they specifically mentioned adaptation in the abstract
- some modelling articles (such as those discussing the pros and cons of various models on impacts) have not been included, despite possibly falling within the adaptation spectrum
- research connected to adaptation (disaster management, planning, etc.) was probably not captured unless it directly mentioned climate change
- neither NCCARF nor FORNSAT received a list of research that was determined not to meet the criteria. As a result, there is a risk that eliminated research would have been considered relevant by NCCARF or FORNSAT representatives. This risk was mitigated by asking FORNSAT representatives to nominate additional research.

A final limitation of this work is project timing. Literature was gathered between August and October 2012; research completed after October and research not publicly available during this time was not included unless nominated by NCCARF or FORNSAT. However, in order to incorporate the majority of NCCARF research, draft reports commissioned by NCCARF were considered. Many of these reports are still undergoing peer review and are not yet available publicly. Draft research incorporated into this synthesis is denoted as such in the reference (e.g. Smith 2013D).

Completed first drafts of some NCCARF commissioned research were also not yet available for inclusion in the synthesis. In order to include these projects in the database, the researchers were asked specific questions about their research and its relevance to government decision-makers; their answers were used to populate the relevant database fields.

AECOM recognises that the inclusion of incomplete NCCARF research but not research in progress from other agencies, universities, government bodies and institutions (e.g. CSIRO) is an inconsistency and a limitation of this project.

## 1.4 The role of government in adaptation

Government and private parties both have essential parts to play in supporting adaptation to climate change. Government is responsible for managing risks to public goods and assets (including the natural environment) and to government service delivery Businesses and individuals are best placed to manage the risks to their own private assets and income. However, government is also responsible for creating an institutional, market and regulatory environment that supports and promotes private adaptation to climate change (DCCEE 2012).

The three levels of government in Australia have different roles to play in climate change adaptation. In some cases, adaptation will be best managed by an individual state or territory, whereas in other cases it will require collaboration across tiers of government and jurisdictions (DCCEE 2012). The Commonwealth will need to take a leadership role in climate change adaptation, driving and coordinating national reform efforts while managing the key assets under its control (DCCEE 2012).

State government, the primary audience for this report, delivers a wide range of services, administers a significant body of legislation, and manages important assets and infrastructure – all of which are likely to be directly impacted by climate change (DCCEE 2012). To assist with adaptation and encourage climate resilience and adaptive capacity, state government's primary roles are to:

- collaborate with Commonwealth and other states/territories to provide local and regional science and information
- manage risks and impacts to public assets, infrastructure and services
- through planning, policy and legislation, encourage effective adaptation by asset and infrastructure owners and managers (both public and private)
- collaborate with other jurisdictions when necessary to manage risks and provide emergency services
- work with the Commonwealth and other jurisdictions to establish and implement national adaptation priorities, to improve adaptive capacity, to strengthen climate resilience in vulnerable communities, to establish a consistent approach to regulation and education, and to implement monitoring and evaluation of adaptation responses
- promote risk management responses by government and the private sector through appropriate forums and communication channels
- ensure regulatory frameworks promote effective adaptation by private parties, utilising market mechanisms when most likely to be effective
- support local government in efforts to build resilience and adaptive capacity in the local community and in creating and implementing policies and regulations consistent with state government adaptation approaches (DCCEE 2012).

Adaptive responses to climate change are often localised, meaning responses and their benefits depend on location and local circumstances. A decentralised approach that strongly emphasises local or regional action is often most effective and efficient (Cimato and Mullan 2010). For this reason, local governments are vital to addressing the impacts to climate change, and the coordination between state and local government is especially important. Local government is best positioned to inform state government and the Commonwealth of local and regional needs, to communicate with their communities directly, and to respond to local changes in an appropriate and timely manner (DCCEE 2012).

Table 2 presents the key functions of the Queensland Government and the potential climate change impacts that are likely to affect each department's areas of responsibility. An understanding of the duties of different departments and how climate change will affect them and their constituents can help determine the role each part of state government can play, or their sphere of influence, in adaptation planning and action.

**Table 2: Key functions of Queensland Government and potential climate change impacts**

| | |
|---|---|
| **Department of Premier and Cabinet** | **Key functions** |
| | Assists and provides specialist policy advice to the Premier and Cabinet, Ministers and agencies |
| | Policy, advice, coordination and Cabinet support and service |
| | Supports Cabinet and Cabinet Committee decision-making |
| | Legislative drafting, advisory and information service supporting the Queensland reconstruction effort |
| | **Potential climate change impacts** |
| | Impacts of extreme climate events on government services, infrastructure, natural assets and community wellbeing |
| | Broader transitional impacts on the state economy |
| **Department of State Development, Infrastructure and Planning** | **Key functions** |
| | Key functional areas include biosecurity, catchment management, crown land management, energy fisheries, food security and agriculture sustainability, marine parks, regional development, rural assistance, tourism, water management, and state development |
| | Fast-track delivery of major resource and industrial development projects |
| | Diversify and build resilience in regional and state economies |
| | Re-empower local governments and their communities to plan for their futures |
| | **Potential climate change impacts** |
| | Changes to infrastructure and service demands |
| | Impacts on vulnerable members of the community |
| | Increasing cost and demand for electricity and water |
| | Increasing vulnerability and structural adjustment for regional economies |
| | Opportunities for development of new industries |
| | Increasing number of extreme events |
| **Department of Treasury and Trade** | **Key functions** |
| | Provides core economic and financial policy advice to the Treasurer and other key stakeholders |
| | Assists Queensland companies to increase their global competitiveness and expand markets |
| | Coordinates regulatory and sectoral reform across Government to enhance productivity |
| | Provides research, advice and direction to support the Government's objectives in economic, regulatory and sectoral reform and governance |
| | Investigates and evaluates funding, procurement and delivery models for the state's infrastructure |
| | Responsible for the Motor Accident Insurance Commission, Queensland Treasury Corporation and the Queensland Future Growth Corporation |
| | **Potential climate change impacts** |
| | Negative impacts of climate change on local, state and national economies |
| | Increasing cost of providing and maintaining government assets and services |

| | |
|---|---|
| **Department of Health** | **Key functions** |
| | Provides a range of services aimed at achieving good health and wellbeing for all Queenslanders |
| | Manages and delivers a range of services through a network of 17 Hospital and Health Services and the Mater Hospitals |
| | **Potential climate change impacts** |
| | Increasing physical and mental impacts on health from extreme weather events |
| | Increasing prevalence of some vector-borne and respiratory diseases |
| **Department of Education, Training and Employment** | **Key functions** |
| | Delivers world-class education and training services for people at every stage of their personal and professional development |
| | Ensures Queenslanders have the education and skills they need to contribute to the economic and social development of Queensland |
| | **Potential climate change impacts** |
| | Increasing need for climate change–related science and knowledge |
| | Need to support communities vulnerable to the impacts of climate change |
| **Department of Police** | **Key functions** |
| | To deliver quality policing services 24 hours a day |
| | **Potential climate change impacts** |
| | Increasing physical and mental impacts on health from extreme weather events |
| | Impacts on vulnerable members of the community |
| | Increasing social impacts (e.g. conflict or violence) due to extreme weather events |
| **Department of Community Safety** | **Key functions** |
| | Provides ambulance, fire and rescue, corrective and emergency services to Queensland. |
| | **Potential climate change impacts** |
| | Increased demand for community services due to extreme weather events and warmer and drier conditions |
| | Impacts on vulnerable members of the community |
| **Department of Justice and Attorney-General** | **Key functions** |
| | Responsible for administering justice in Queensland |
| | Leads policy development and delivers services to ensure safe, fair and productive work environments |
| | **Potential climate change impacts** |
| | Sea level rise impacts on coastal planning (legal disputes) |
| | Increased demand for emergency services during extreme weather events |
| **Department of Transport and Main Roads** | **Key functions** |
| | Plans, manages and delivers Queensland's integrated transport environment to achieve sustainable transport solutions for road, rail, air and sea |
| | **Potential climate change impacts** |
| | Damage to transport infrastructure from extreme events as well as warmer and drier conditions |
| | Increased maintenance requirements |
| | Disruption to transport networks |
| **Department of Housing and Public Works** | **Key functions** |
| | Leads Queensland Government's capital works building program |
| | Helps build and maintain the public facilities, such as schools, public housing, hospitals, police stations and courthouses |
| | Lead agency for government procurement, disaster management and recovery, office support services (fleet, printing and office supplies) |
| | **Potential climate change impacts** |
| | Increased demand for emergency services during extreme weather events |
| | Impacts on service provision for housing and public facilities |
| | Impacts on vulnerable members of the community |

| | |
|---|---|
| **Department of Agriculture, Fisheries and Forestry** | **Key functions** |
| | Promotes profitable primary industries |
| | Provides expertise and support to assist the state's food and fibre industries to increase productivity, improve sustainability, grow markets and adapt to change |
| | Delivers world-class research and development |
| | Provides leadership on industry policy |
| | Protecting industries against pests, diseases and maintaining animal welfare standards, managing fisheries sustainably and maximising the value of state-owned forests |
| | **Potential climate change impacts** |
| | Increased vulnerability and risks for certain regions, potentially changing the suitability of land for development, agriculture or other uses |
| | Increased forest vulnerability to fire and lack of water |
| | Increased heat stress and water allocation for livestock, limiting production |
| | Increased exposure to pests and disease |
| | Increasing prevalence of some vector-borne, water-borne and insect-borne diseases, increased pressure on crop and animal protection |
| | Reduced cropping yields and reduction in food and fibre quality and suitability |
| **Department of Environment and Heritage Protection** | **Key functions** |
| | Implements programs to conserve and enhance the health of the state's natural environment ecosystems, including its landscapes and waterways, as well as its native plants and animals and biodiversity |
| | Facilitates project approvals and industry compliance |
| | Develops and reforms legislation, plans and programs to support front-line environmental service delivery, manages ecosystems, waste agenda and ongoing role in climate change adaptation |
| | **Potential climate change impacts** |
| | Negative impacts of climate change and more frequent extreme events on ecosystems, biodiversity and water resources |
| | Changes in ecosystem and land use management needs |
| | Sea level rise impact on coasts |
| | Decline in rainfall and reduction in both runoff-to-surface water storages and recharge to aquifers |
| | Increased evaporation rates driving demand |
| | Increased incidence of more severe rainfall events and flooding |
| | Changes in flora and fauna habitat ranges and distribution. Also changes to reproduction timing and species interactions |
| **Department of Natural Resources and Mines** | **Key functions** |
| | Management of the state's natural resources: land, water and minerals for economic, environmental and social benefits |
| | Support for the safety and health of all Queensland miners and people working in allied industries |
| | **Potential climate change impacts** |
| | Negative impacts of climate change and more frequent extreme events on ecosystems and water resources |
| | Changes in ecosystem and land use management needs |
| | Decline in rainfall and reduction in both runoff-to-surface water storages and recharge to aquifers |
| | Increased evaporation rates driving demand |

| | |
|---|---|
| **Department of Energy and Water Supply** | **Key functions** |
| | Delivers innovative policy, planning and regulatory solutions in partnership with our stakeholders to support cost-effective, safe, secure and reliable energy and water supply |
| | **Potential climate change impacts** |
| | Decline in rainfall and reduction in both runoff-to-surface water storages and recharge to aquifers |
| | Increased evaporation rates driving demand |
| | Increased incidence of more severe rainfall events and flooding |
| | Negative impacts of climate change on local, state and national economies |
| | Changes to energy demands and increased energy costs |
| | Increased costs and risks to business |
| | Potential for new business development |
| **Department of Local Government, Community Recovery and Resilience** | **Key functions** |
| | Supports the autonomy, authority and accountability of local governments in legislative reform, financial sustainability, capacity building and governance and decision-making |
| | Oversees the legislative and regulatory framework in which local governments operate<br>Leads and guides the government's work to increase community and infrastructure resilience |
| | **Potential climate change impacts** |
| | Negative impacts of climate change on local, state and national economies |
| | Increasing cost of maintaining local government assets and services |
| **Department of Communities, Child Safety and Disability Services** | **Key functions** |
| | Provides wellbeing, safety, and inclusion support and services to communities |
| | Designs legislation, policies and programs that support revitalisation of service delivery |
| | **Potential climate change impacts** |
| | Impacts on vulnerable members of the community |
| | Impacts of extreme climate events on government services, infrastructure, natural assets and community wellbeing |
| **Department of Science, Information Technology, Innovation and the Arts** | **Key functions** |
| | Develops and coordinates science and ICT policy across the Queensland Government |
| | Supports and invests in research and development |
| | Improves government service delivery through efficient use of ICT services and shared services |
| | Helps Queensland businesses and consumers benefit from current and emerging digital technologies and services |
| | **Potential climate change impacts** |
| | Increased need for climate change-related science and knowledge |
| | Impacts of extreme climate events on government services, infrastructure, natural assets and community wellbeing |
| | Broader transitional impacts on the state economy |
| **Department of National Parks, Recreation, Sport and Racing** | **Key functions** |
| | Manages public national parks, marine parks, forests, declared fish habitat areas, resources reserves and conservation parks |
| | Promotes active lifestyles by providing recreational and sporting opportunities |
| | Manages Queensland’s racing industry |
| | **Potential climate change impacts** |
| | Negative impacts of climate change and more frequent extreme events on parks and ecosystems |
| | Changes in land use management needs |
| | Changes to rainfall and evaporation levels affecting quality and useability of sporting grounds |
| | Impacts of extreme weather events on community wellbeing |

| | |
|---|---|
| **Department of Tourism, Major Events, Small Business and the Commonwealth Games** | **Key functions** |
| | Drives tourism and attracts new investment in the tourism industry |
| | Delivers information to help small business operators achieve sustainable and resilient long-term growth |
| | Secures and facilitates the delivery of majors events in Queensland |
| | **Potential climate change impacts** |
| | Negative climate change impacts and more frequent extreme events affecting nature-based tourism assets such as national and marine parks |
| | Negative impacts of climate change on local, state and national economies |
| | Increased costs and risks to small business, tourism industry and major events |
| | Changes in flora and fauna habitat ranges |
| | Sea level rise impact on coasts |
| | Disruption to transport networks |
| **Department of Aboriginal and Torres Strait Islander and Multicultural Affairs** | **Key functions** |
| | Leads the development of policies and programs to close the gap in life outcomes for Indigenous Queenslanders |
| | Engages with Aboriginal and Torres Strait Islander people across Queensland and coordinates government activity on Indigenous reforms at a local, regional, state and national level |
| | Responsible for coordinating the implementation of multicultural policy across government departments and working with communities to promote harmonious community relations |
| | **Potential climate change impacts** |
| | Impacts on vulnerable members of the community |
| | Impacts of extreme climate events on government services, infrastructure, natural assets and community wellbeing |

## 1.5 The adaptation challenge for government and the role of research

Climate change is one of the most pressing issues of our time and one of the most challenging to address. It exceeds the capacity of any one actor – be that government or the private sector – to understand and respond. In fact, the motivation and actions of all individuals and all levels of government are critical and interactive components of the solution. Mitigation efforts to reduce greenhouse gas emissions are important, but some level of climate change has occurred and further change is inevitable. There is considerable uncertainty related to future climate change, but sufficient evidence exists to start planning adaptation action. Increasingly frequent and extreme weather events, combined with continued economic growth, suggest that action to adapt to climate change is increasingly urgent. Pre-emptive adaptation action is also likely to be the most efficient, effective, equitable and sustainable approach to managing the risks associated with climate change (Department for Environment, Food and Rural Affairs 2010).

Adaptation to climate change clearly presents new challenges and opportunities for decision-makers. While decision-makers may aim to make sensible decisions that take into account current and future climate change, they frequently lack a clear understanding of their own vulnerability to climate variability (Preston and Stafford Smith 2009). Furthermore, as climate change and adaptation are complex topics, policymakers may feel the need to wait for science to provide clear answers before taking action. However, due to the complexity of climate science, absolute certainty will likely never be achieved. This creates a fundamental challenge, as there are a number of areas of public policy and management directly related to climate change that still have critical unanswered questions (Morton et al. 2009). Decision-makers are being asked to use their partial knowledge and the current state of scientific knowledge to implement specific policies and measures; they are finding this a difficult undertaking (Morton et al. 2009; Preston and Stafford Smith 2009).

According to the Australian Department of Climate Change and Energy Efficiency (DCCEE 2011), governments face numerous barriers to adaptation-related decisions, including:

- limits to the availability of or access to information as well as the understanding, funds, expertise and other capacity necessary to make appropriate decisions and implement the actions that flow from these decisions
- a misunderstanding of the nature and timing of climate change, especially the perception that it will occur in a slow and linear manner
- emerging awareness of a range of institutional, regulatory and other factors which act to constrain action to prepare for the impacts of climate change.

To address some of these challenges, Australian state and territory governments frequently fund or undertake research activities to support their direct needs. However, state and territory government decision-makers are also reliant on independent research. Utilising this research effectively is challenged by a number of factors, including its discoverability, accessibility, direct relevance to the context (physical, socio-economic, ecological or geographical), clarity, internal processes and capacity of decision-makers (Morton et al. 2009; Preston and Stafford Smith 2009). In its attempt to make a large portion of Australian adaptation research easily accessible and directly relevant to state and territory decision-makers, this synthesis aims to help reduce this barrier.

# 2. Queensland climate challenges

In order to plan for climate change and prioritise adaptation activities, it is important to understand what climatic challenges are occurring now and what changes will be faced in the future. This section of the report highlights the current state of the climate, the climatic changes anticipated, and how these changes are expected to affect Queensland. Recognising that considerable activity has already occurred in the state to address these climatic challenges, it also highlights Queensland's current adaptation priorities and current and past activities.

## 2.1 Queensland's current and future climate

Queensland's climate is getting hotter and has been on a warming trend for some time. Data on mean temperature in Queensland for the last hundred years shows a warming trend slightly stronger than the global average, with the greatest warming occurring in the south of the state, particularly south-western Queensland (DERM 2011). The daily temperature range has decreased throughout the majority of Queensland, as the minimum temperature has increased at a faster rate than the maximum temperature (DERM 2011). Continued warming is predicted for Queensland, with the inland regions predicted to have the greatest increase in temperature (DERM 2011).

Heavy rainfall events are a common and natural feature of the state's climate. Although rainfall in Queensland is both spatially and temporally variable, a sustained decrease in rainfall has been recorded along the east coast since the 1950s (DERM 2011). Predictions for rainfall patterns in Queensland are for decreased precipitation in some areas and stable in others (DERM 2011). However, there is no consensus among scientists on the scale or direction of rainfall changes with the state (Steffen et al. 2012).

In north Queensland, tropical cyclones can pose a major threat to people, infrastructure and natural systems. The number of cyclones is predicted to decrease or remain the same; however, the cyclones that do occur are expected to be stronger, with greater rainfall rates and maximum wind speeds (Steffen et al. 2012). There may also be an increase in the number of tropical cyclones occurring in regions of south-east Queensland.

Sea level rise in Queensland varies regionally but has generally been observed at a rate at or above the global average (Steffen et al. 2012). Increased regional sea level rise is predicted to continue, particularly along the east coast and gulf region, exacerbating predicted global sea level rise impacts on Queensland's coasts (DERM 2011). Sea level rise in synergy with storm surges and extreme wind and rain events are likely to cause coastal inundation, flash flooding and erosion of the state's coast.

## 2.2 Climate change impacts for Queensland

Climate change represents a significant threat to people, places and the environment. Combined projected changes to temperature, rainfall, sea levels and storms will place unprecedented stress on many systems and communities. The major drivers of ecological, social and economic impacts of climate change are similar nationally, but vary in their intensity and effects regionally. The following summarises a selection of expected impacts in Queensland by sector.

*Health and wellbeing*

Rainfall, temperature and humidity changes can contribute to the spread of mosquito-borne infectious diseases, including Dengue Fever. The mosquito that carries Dengue Fever is usually confined to northern Queensland; however, the geographic range of this mosquito is expected to expand southwards if the climate becomes hotter and wetter (Steffen et al. 2012).

Heatwaves, cyclones, floods, bushfires and other extreme events can all have a number of adverse impacts on human health, including injury, disease and death. During the intense floods of December 2010 and January 2011, 33 people died (Steffen et al. 2012). Identified vulnerable populations from recent flood events include the elderly (including nursing home residents), businesses and residents who cannot obtain flood insurance, and new migrants (Apan et al. 2010).

Existing social and economic disadvantages may also increase the vulnerability of some remote Indigenous communities, particularly where multiple disadvantages prevail (e.g. poor health and low income) (SCRGSP 2007, in McNamara et al. 2011).

*Fisheries, forestry and agriculture*

Higher temperatures, changes in rainfall, and extreme events will affect the future productivity of agriculture in the state. Events such as floods can have major financial implications on primary producers, due to the losses of crops and livestock and property damage. Rising carbon dioxide levels may, however, have some positive benefits for agriculture, as some plants can become more efficient at using water in a high carbon dioxide environment (Steffen et al. 2012). That said, the benefits are unlikely to outweigh the negative aspects of climate change.

Queensland's beef industry is likely to be affected by climate change and could decline substantially by 2050 due to cattle heat stress (Steffen et al. 2012). Increasing temperatures could also increase the risk of infection and disease to more cattle as pests and parasites shift their distribution southward. Under climate change, cattle ticks are expected to reduce in numbers in Queensland's north and increase in the south (White et al. 2003, in Steffen et al. 2012).

Queensland is Australia's primary prawn-producing state. As a result of climate change, prawn farms are at risk of damage from flooding and extreme events, such as cyclones (QFF 2008, in Steffen et al. 2012). Rising ocean temperatures and changes in ocean productivity may also affect coastal fisheries.

*Natural environment*

More than 200 of Queensland's ecosystems are considered endangered and more than 500 are considered vulnerable (DERM 2010, in Steffen et al. 2012). Climate change presents an additional threat to the state's unique and fragile biodiversity. Animal and plant species in the high altitude areas of the Wet Tropics Heritage Area are particularly vulnerable in the face of increased temperatures and reduced rainfall (Shoo et al. 2011, in Steffen et al. 2012).

Bushfires are also expected to increase in frequency and intensity in Queensland's tropical savannahs, grasslands and dry eucalypt forests (Steffen et al. 2012). This will affect the ability of ecosystems in these areas to recover from fire damage.

Queensland's diverse marine habitats (coral reefs, mangroves, sandy beaches, saltmarshes and seagrass beds) are also vulnerable to climate change, particularly sea level rise and changes in sea temperature. In the Great Barrier Reef, a water temperature rise between one and two degrees above normal for a period of over six weeks can lead to coral 'bleaching'; repeated bleaching events can lead to disease, starvation or death (Steffen et al. 2012).

*Community and infrastructure*

Most Australians live in cities that extend along the Australian coastline, and Queensland is no exception. In South East Queensland, rapidly expanding coastal developments are occurring north and south of Brisbane. A sea level rise of 110 centimetres over this century (compared with 1990 levels) would threaten up to 1,400 commercial buildings and between 35,900 and 56,900 residential buildings (not including new developments) in Queensland (DCC 2009, in Steffen et al. 2012; DCCEE 2011).

High sea level events can lead to coastal erosion and eventual coastal retreat (Steffen et al. 2012). Beach erosion problems on the Gold Coast have occurred because many developments, initially holiday cottages, are now multi-story buildings built close to the ocean without adequate buffers (Helman et al. 2010). Within 110 metres of erodible coastline in Queensland, there are approximately 15,200 residential buildings (Steffen et al. 2012).

Most towns and cities in Queensland are built on flood plains; however, a recent review of planning schemes found that only 37 per cent of schemes contained any flood-related mapping (Wenger et al. 2012D). During 2008, flooding cost state and local governments approximately $234 million in damage to infrastructure in flooding that covered approximately one million square kilometres (or 62 per cent of the state) (Apan et al. 2010).

Mason et al. (2012D) found that in the 2010/11 floods, more than 28,000 properties were inundated in Queensland, with around half of these in Brisbane. In Brisbane, around 90 per cent of those flooded were in areas developed prior to any form of planning or building controls relating to floodplain management (i.e. the late 1970s) and the vast majority experienced flooding during the 1974 floods (QFCI 2012, in Mason et al. 2012D).

*Business and industry*

Climate change may result in adverse business outcomes as a result of business interruptions, increased investment or insurance costs, declining financial measures such as value, return and growth. Business and industry also influence the resilience and adaptive capacity of a community or region by providing employment, tax revenue and in some cases critical services (Kuruppu et al. 2013D).

## 2.3 Queensland adaptation priorities and activities

The Queensland Government has not formally defined its climate change adaptation priorities regarding research or policy; however, in October 2012, the government made a public commitment to update Queensland's climate change adaptation strategy (Estimates Committee 2012). Additionally, Queensland has a history of adaptation action. Queensland was the first Australian jurisdiction to mandate the consideration of climate change during planning and development assessment under its regulatory planning framework (Gurran et al. 2011). This approach is being tested in the Townsville Coastal Hazard Adaptation Strategy Pilot Project. This project is intended to help pave the way for coastal councils to develop policies and strategies to prepare coastal communities for projected sea level rise, storm-tide inundation and coastal erosion, including the impacts of climate change up to 2100 (DEHP 2012).

In response to the recent floods in January 2013, the Queensland Government is also acting to mitigate the impact of and build resilience to natural disasters to help protect Queensland's towns and infrastructure. The Department of Local Government has been expanded to include a Community Recovery and Resilience portfolio, which will lead and guide the government's work to increase community and infrastructure resilience (Queensland Government 2013a). Queensland's Minister for Local Government, Community Recovery and Resilience will take charge of the Queensland Reconstruction Authority and will work closely with local communities. This has included amendments to the *Queensland Reconstruction Authority Act 2011* in order to improve the resilience of communities for potential disaster events.

In April 2013, the Queensland Government released its Coastal Protection State Planning Regulatory Provision; this coastal protection policy establishes the requirements for coastal protection within the state. It promotes, to the greatest extent practical, the conservation of coastal zones in their natural state in non-urban areas and requires an evaluation of the risks to life and property, including the risk of sea level rise (DSDIP 2013).

The Queensland Government also announced in June 2013 an allocation of $4.2 billion in 2013–14 for natural disasters recovery, as well as resilience efforts. Premier Campbell Newman and Treasurer Tim Nicholls emphasised that Queensland is determined to rebuild communities in a way that increases resilience and ensures new infrastructure is better than what previously existed (Queensland Government 2013b).

Other current and past initiatives of the Queensland Government to support climate adaptation measures include:

- creating of regional climate change summaries in 2009 to assist local government, business, industry and the community understand the potential impacts and prepare for future climate variability (DEHP 2013a)
- providing historical and projected data on climate and rainfall, variability to support the agriculture sector (DEHP 2013b)
- working with CSIRO on climate modelling to provide new information on how the climate is changing (DEHP 2013c).

# 3. Research relevant to Queensland

This project primarily draws upon NCCARF research. However, the synthesis findings (Section 4) also utilise a selection of policy-relevant research gathered through other Australian sources. This section of the report provides further information on the research collected and synthesised for this project and, in particular, highlights which research studies occurred in Queensland.

## 3.1 Identified adaptation research

Over 450 research reports (including NCCARF research) were gathered in total and included in the database that accompanies this project. Figure 2 displays the number of research reports collected by state/territory to which they are relevant (meaning that state/territory was stated as the study area). A large portion of the research collected had national relevance and did not contain case studies specific to a state/territory. For the research that contained case studies, Queensland and Victoria were most commonly studied, followed by New South Wales.

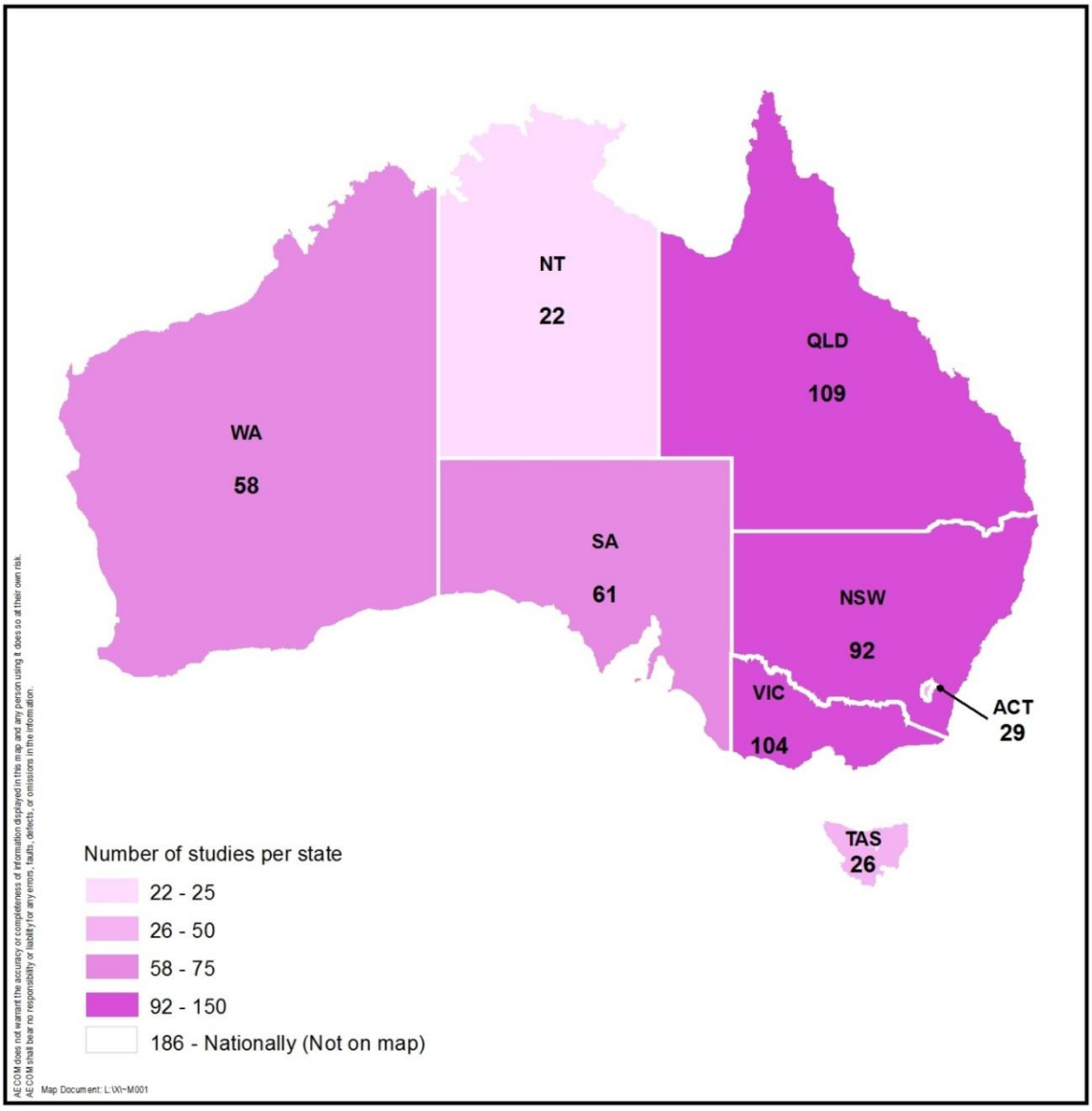



**Figure 2: NCCARF and non-NCCARF research by state/territory**

A selection of the research gathered for the database was included in the synthesis (Section 4). Some NCCARF reports were unable to be included as research drafts were not available at the time of synthesis drafting. Others were excluded as their content was not directly relevant to state government policy- and decision-makers. A full list of excluded projects is included in Appendix D. Up to 15 pieces of research specific to each state/territory but

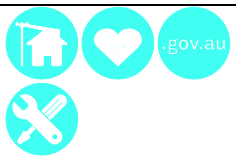
not part of the NCCARF-funded research pool were selected and reviewed for synthesis in addition to the NCCARF reports. The research was selected based on its relevance to state government policy.

## 3.2 Queensland-specific research

Research projects used to inform and shape this synthesis were selected for their specific relevance to Queensland, and are listed in Table 3**.** Projects were chosen on the basis that their research included at least one Queensland-specific location or case study, although not all projects were delivered by Queensland-based research organisations. The purpose of this table is to help readers locate a particular report in Queensland that they may wish to find and read further. Note that Table 3 does not include the research reports reviewed that only covered climate change impacts and Queensland Government activities and priorities, which were referenced in Section 2.0. These reports are listed in the bibliography.

**Table 3: Queensland-specific research**

| Lead Author | Status | Year | Title | Sectors |
|---|---|---|---|---|
| A. Apan | Final | 2010 | The 2008 floods in Queensland: a case study of vulnerability, resilience and adaptive capacity |  |
| I. Baker | Final | 2012 | Local government response to the impacts of climate change: an evaluation of local climate adaptation plans |  |
| D. Bird | Draft | 2013 | Future change in ancient worlds: Indigenous adaptation in northern Australia |  |
| D. Bird | Final | 2011 | Impact of the 2010/11 floods and the factors that inhibit and enable household adaptation strategies |  |
| D.A. Black | Draft | 2013 | Heat-ready: heatwave awareness, preparedness and adaptive capacity in aged care facilities in three Australian states: New South Wales, Queensland and South Australia. |  |
| H. Boon | Draft | 2012 | Recovery from disaster experience: its effect on perceptions of climate change risk and on adaptive behaviours to prevent, prepare, and respond to future climate contingencies |  |
| J. Burley | Final | 2012 | Integration, synthesis and climate change adaptation: a narrative based on coastal wetlands at the regional scale |  |
| M. Bussey | Final | 2012 | Framing adaptive capacity through a history-futures lens: lessons from the South East Queensland Climate Adaptation Research Initiative |  |
| D.L. Choy | Draft | 2013 | Understanding coastal urban and peri-urban Indigenous people's vulnerability and adaptive capacity to climate change |  |
| DERM | Final | 2010 | Increasing Queensland's resilience to inland flooding in a changing climate: final report on the Inland Flooding Study |  |

| Lead Author | Status | Year | Title | Sectors |
|---|---|---|---|---|
| L. Dobes | Draft | 2012 | Benefits and costs of provision of post-cyclone emergency services: harnessing private sector logistics for emergency food and water supplies in flood prone areas |  |
| L.S. Evans | Final | 2011 | Limits to climate change adaptation in the Great Barrier Reef: scoping ecological, institutional and economic limits |  |
| C.S. Fletcher | Draft | 2013 | Costs and coasts: an empirical assessment of physical and institutional climate adaptation pathways |  |
| W.L. Hadwen | Final | 2011 | Climate change responses and adaptation pathways in Australian coastal ecosystems: synthesis report |  |
| P. Helman | Final | 2010 | Storm tides, coastal erosion and inundation |  |
| K. Hussey | Draft | 2013 | An assessment of Australia's existing statutory frameworks, associated institutions, and policy processes: do they support or impede national adaptation planning and practice? |  |
| J. Kellett | Final | 2011 | Learning from regional climate analogues |  |
| D. Keogh | Final | 2011 | Resilience, vulnerability and adaptive capacity of an inland rural town prone to flooding: a climate change adaptation case study of Charleville, Queensland, Australia |  |
| A.S. Kiem | Final | 2012 | Limits and barriers to climate change adaptation for small inland communities affected by drought |  |
| A.S. Kiem | Final | 2010 | Learning from experience: historical case studies and climate change adaptation |  |
| D. King | Draft | 2012 | Planning, building and insuring: adaptation of built environment to climate change induced increased intensity of natural hazards |  |
| S. Kinnear | Draft | 2012 | Network governance and climate change adaptation: collaborative responses to the Queensland floods. Social networks analysis: bridging degrees of separation to enhance climate change adaptation |  |
| N. Kuruppu | Draft | 2013 | Understanding the adaptive capacity of small-to-medium enterprises (SMEs) to climate change and variability |  |

| Lead Author | Status | Year | Title | Sectors |
|---|---|---|---|---|
| Y. Li | Final | 2011 | Cyclone damage risks caused by enhanced greenhouse conditions and economic viability of strengthened residential construction |  |
| A. Loch | Draft | 2012 | The role of water markets in climate change adaptation |  |
| N.A. Marshall | Final | 2010 | Understanding social resilience to climate variability in primary enterprises and industries |  |
| M. Mason | Draft | 2012 | Damage to buildings during the 2010–2011 Eastern Australia flooding events |  |
| D. McEvoy | Final | 2013 | Enhancing the resilience of seaports to a changing climate: synthesis – implications for policy and practice |  |
| K.E. McNamara | Final | 2011 | Limits to climate change adaptation for low-lying communities in the Torres Strait |  |
| P. Memmott | Draft | 2013 | Aboriginal responses to climate change in arid zone Australia |  |
| J.P. Reser | Final | 2012 | Public risk perceptions, understandings, and responses to climate change and natural disasters in Australia, 2010 and 2011 |  |
| A. Roiko | Final | 2012 | Socio-economic trends and climate change adaptation: The case of South East Queensland |  |
| V. Sharma | Final | 2013 | Extractive resource development in a changing climate: learning the lessons from recent weather events in Queensland, Australia |  |
| H. Shearer | Final | 2013 | The capacities of private developers in urban climate change adaptation |  |
| W. Steele | Draft | 2013 | Learning from cross-border mechanisms to support climate change adaptation in Australia: Every state for themselves? |  |
| M.G. Stewart | Final | 2011 | Risk assessment of climate adaptation strategies for extreme wind events in Queensland |  |
| C. Wenger | Draft | 2012 | Living with floods: key lessons from Australia and abroad |  |

## 3.3 Queensland locations of synthesis research

Figure 3 maps the study locations and study regions within Queensland for the research included in this synthesis. The purpose of this map is to highlight the cities, towns and regions where research has occurred, as this information may be relevant to the Queensland Government's work with regions and local councils and emphasises locations where additional research may need to occur.

This map demonstrates that research has been concentrated along the coast, particularly in and around Cairns and Brisbane. Case study locations were often chosen because they had previously experienced extreme events, such as floods. Regions examined include the Bowen Basin, Lockyer Valley and South East Queensland. A few locations were studied in more than one project.

Appendix C includes summaries of the NCCARF-funded research that occurred in Queensland.

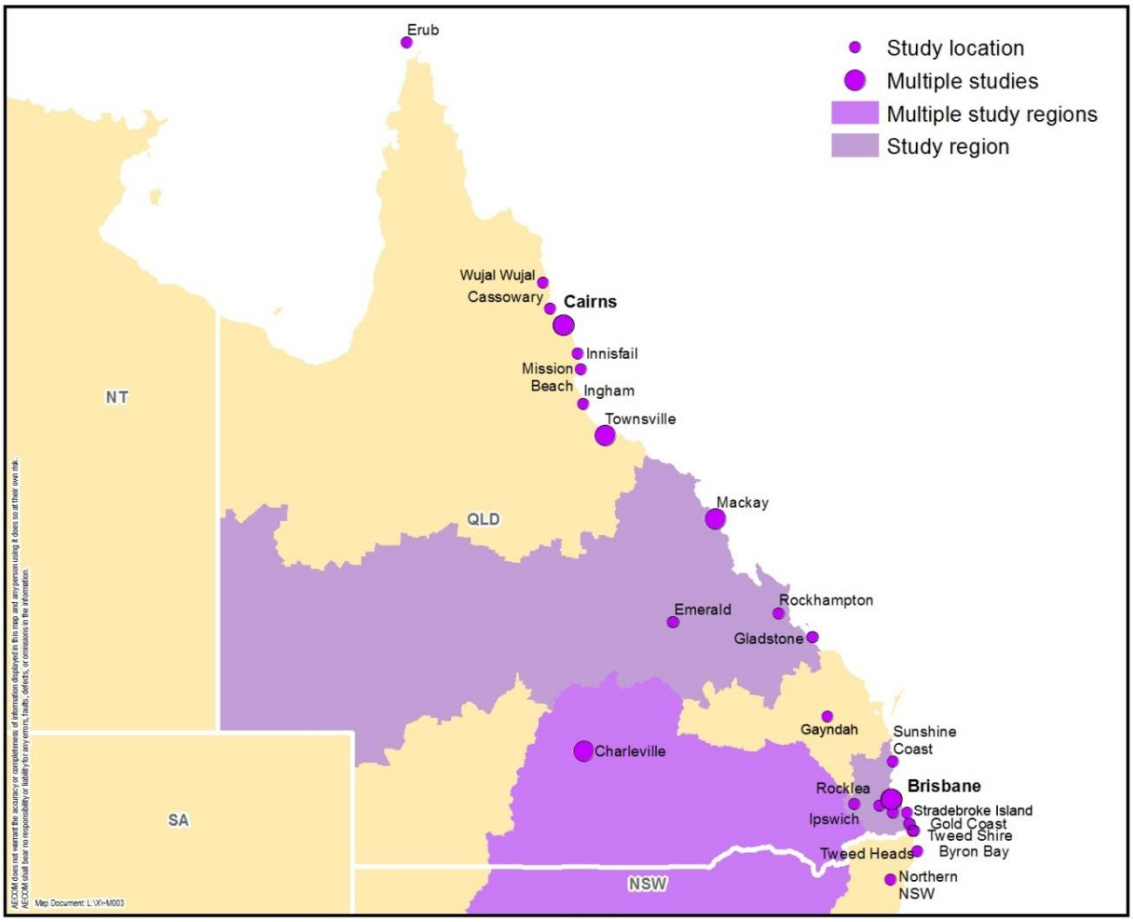



**Figure 3: Case study locations in Queensland**

# 4. Research findings

The role of a synthesis is to value add to existing research by breaking down individual research reports and aggregating findings to form a new whole based on common threads or themes of learning. A synthesis of research is also usually formulated in an attempt to find answers to a specific question or a series of questions. For this synthesis, that question was: "What are the common emerging adaptation research lessons that can be used by state and territory decision-makers, particularly with regards to policy-setting?"

This section of the report presents the main findings of the synthesis by the identified themes. It is important to note, however, that though findings have been categorised into one theme, there are overlapping and cross-theme relationships between the lessons described.

The findings described are the opinions and conclusions of the researchers and are not necessarily the professional opinion of AECOM. It is also important to recognise that, despite best efforts to aggregate findings across multiple research reports, the distinct focus of some of the research has not enabled some findings to be supported by more than one research study.

## 4.1 Increasing resilience and adaptive capacity

Vulnerability (be that biophysical or socio-economic) is intrinsically linked with adaptation through the consideration of resiliency and adaptive capacity. The IPCC WG2 (2007) defines vulnerability as "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" (p. 883). This concept is important as many adaptation actions focus on increasing a community's or system's ability to handle exposure to climate change, that is, increasing its adaptive capacity, and thereby reducing its vulnerability. Increasing adaptive capacity can relate to changes in resources (e.g. financial or human capital) and institutional or governance arrangements.

'Resilience' is a related term that can create confusion as it could be interpreted to mean returning to a prior state after a disturbance, while 'adaptation' usually refers to a fundamental shift or transformation in state (Preston and Stafford Smith 2009). However, often resilience simply refers to a community or system's robustness or its ability to undergo change while maintaining its integrity. This confusion in terminology is discussed further in Section 4.1.3.

This section outlines the emerging themes identified in the research that are relevant to increasing the resilience and adaptive capacity of communities, systems or individuals. It includes a discussion of pre/post-extreme event support, lessons regarding building and maintaining community resilience, messaging and communication about climate change and adaptation, and community expectations for government.

### 4.1.1 Pre- and post–extreme event support

*The findings in this section are particularly relevant for emergency management.*

Many of the findings presented below and in Section 4.2, Learning from Experience, deal with disaster risk reduction (DRR); DRR is the practice of reducing the disaster risks from extreme events through the reduction of underlying factors that contribute to vulnerability. While technically separate practices, DRR and climate change adaptation converge on the common goals of risk and vulnerability reduction. They differ in multiple ways: two key distinctions are that DRR addresses broader risks, beyond climate, including volcanic eruptions and earthquakes, which adaptation does not; and that adaptation considers longer-term changes to climate while DRR is mainly interested in extremes. However, at the local level, many communities also do not see a separation between the two (Gero et al. 2010). The historical experiences of DRR can therefore contribute greatly to climate change adaptation, and the integration of the two is often recommended (Gero et al. 2010).

Key findings for increasing resilience and adaptive capacity pre- and post–extreme events:

- Government financial support post-disaster is complex and could lead to moral hazard and reduced resilience.
- Targeted preparation investment, including subsidising community emergency supplies and SME support, is critical to community economy and wellbeing.
- Adaptation and emergency assistance need to take into account a community's short- and long-term challenges, including broader socio-economic issues.
- Planning for extreme events is important, yet preparedness also needs to be holistic and tested for robustness.

***Government financial support post-disaster is complex and could lead to moral hazard and reduced resilience.*** Provision of government assistance post-disaster is a complicated issue given the complexity and cost of insurance arrangements and the limited capacity of the uninsured to make changes to their homes due to lack of funds (Bird et al. 2011). Nonetheless, some research suggests there is a real risk that this type of financial support could deter some residents from covering their own risk and instil expectations that may be detrimental to a community's long-term resilience (Bird et al. 2011). As stated by Macintosh et al. (2013D, p. 28):

> If there is an expectation that governments will manage the risks, and cover private losses when risks materialise, the incentive to avoid at-risk areas, and to take appropriate preventative action, will be reduced. In a liberal democracy like Australia, where there is a significant social safety net and governments provide extensive emergency assistance, eliminating this expectation would be difficult and could involve considerable political cost.

This may be particularly problematic if people are reluctant to donate to the sources of these funds, such as the Premier's Flood Appeal, as the frequency of extreme events increase, and governments are unable to afford continued assistance (Bird et al. 2011). In addition, Boon et al. (2012D) found that, in some cases, providing financial support from state or federal agencies and NGOs to residents faced with the adverse impacts of floods, bushfires and cyclones does not support resilience and can facilitate a departure from the community, thereby potentially reducing the resilience of the community as a whole.

***Targeted preparation investment, including subsidising community emergency supplies and SME support, is critical to community economy and wellbeing.*** Being financially able to prepare for a disaster is critical for resilience. Boon et al. (2012D) suggest that emergency supplies, preparation kits and other items encouraging a proactive response to extreme weather events should be subsidised. Similar issues for small- to medium-sized enterprises (SMEs) were also noted in Victorian bushfire and flooding case studies by Kuruppu et al. (2013D). Historical disaster response initiatives supporting the economic recovery of SMEs were found to be generally reactive and to fail to specifically address underlying vulnerabilities, such as limited access to financial and human resources, under-insurance and operational location challenges. The effectiveness of these assistance measures was perceived by SMEs to be further limited as a result of:

- the short-term duration of business recovery programs (generally only up to three years following an event)
- the limited support available to SMEs indirectly impacted by climate hazards and in preparing disaster response and recovery. This sentiment has also been raised as an issue between farmers and non-farmers in relation to drought assistance in Victoria (Sherval and Askew 2012)
- lack of consideration of the psychological impacts for SMEs
- difficulties in accessing recovery funds.

These identified shortfalls suggested the importance of ensuring that business continuity for SMEs under climate change is integrated into existing processes and networks (Kuruppu et al. 2013D). This type of approach was undertaken with SMEs in Western Australia in response to drought, where counsellors were assigned to support local businesses with more strategic business planning processes to improve resilience. Given the importance of SMEs to local economies and to community resilience, further consideration needs to be given to more proactive adaptation support to this sector.

***Adaptation and emergency assistance needs to take into account a community's short- and long-term challenges, including broader socio-economic issues.*** Adaptation and response to extreme events cannot be considered in isolation. As noted by Kiem et al. (2010b), the social and economic issues facing many communities (inland, rural) are not just the product of a climate hazard, and to understand them as such underestimates the extent of the problem and reduces the effectiveness of intervention. While the type of

disaster, its intensity and length of its impact will influence resilience, responses need to take into account short- and long-term issues affecting both individuals and the community as a whole.

Planning for multiple levels of preparedness is needed for catastrophic and less severe events and for the onset of rapid and slow events (Boon et al. 2012D). The first step towards enhancing community resilience requires an understanding of the community's strengths and vulnerabilities, its physical characteristics (e.g. local infrastructure), local governance (e.g. disaster policies and plans) and social characteristics (e.g. level of community cohesion) (Boon et al. 2012D). For example, lack of provision within funding contracts (particularly within government contracts) for community service organisations to act in response to and recovery from extreme events, as well as lack of government adaptation policy and guidelines were identified as barriers for these organisations to adapt and act as adaptation enablers for the disadvantaged (Mallon et al. 2013D).

Many adaptation lessons can be learned from decades of drought policy which help illustrate how other external factors, such as the introduction of water trading, commodity prices and aging communities, affect the effectiveness and the equity of interventions. According to Sherval and Askew (2012), local experiences of Victoria's recent drought, particularly in rural towns whose local economies rely on agriculture, are not well understood as a result of the combination of rapidly evolving changes in water market reforms, the drought itself and non-climate–related simultaneous changes (in this case, the changes to the Australian Wheat Board). While many of these challenges have been financial, health impacts have also resulted due to the important social and emotional connections with water for the community. The ongoing resilience and adaptive capacity of these towns is severely challenged by multiple drivers of changes, not just a changing climate (Sherval and Askew 2012; Kiem et al. 2010b). Therefore, support needs to take into account underlying vulnerability and support for longer-term adaptation within the broader community. For example, Exceptional Circumstances payments for farmers can work against communities trying to adapt and transition (Kiem et al. 2010b).

Finally, post-event assistance needs to consider projected future events and the resilience of the community as a whole. This includes changes in frequency and intensity of the same hazard, as well as others where adaptation measures against one risk may introduce new risks from other events – for example, buildings built with lighter, more comfortable materials to handle hot, tropical weather can be maladaptive during a cyclone, increasing the risk of damage from flying debris.

***Planning for extreme events is important, yet preparedness also needs to be holistic and tested for robustness.*** In some Australian states, heatwave plans for aged care facilities are directed by the government. For example, heatwave planning is a major focus of health and safety departments in South Australia. Ninety-three per cent of aged care facilities surveyed by Black et al. (2013D) in South Australia had heatwave plans. In Queensland, 41 per cent of facilities had a dedicated heatwave plan, while dedicated plans were uncommon among NSW aged care facilities.

Only about half of the facilities in South Australia surveyed had back-up generators, though this was more than the aged care facilities in both NSW and Queensland. Many facilities in South Australia also had back-up cooling methods that rely on electricity. This indicates that many aged care facilities have not considered the risk of increased power outages during periods of extreme heat, a necessary consideration for planning to be considered robust and holistic. A number of adaptation options are available to reduce risk, which could be incorporated into asset renewal and maintenance plans. These include provision of water coolers, tinted windows, window awnings and shutters, reflective roof paint, and air conditioning upgrades (Black et al. 2013D).

Black et al. (2013D) also found variable and inconsistent results across the states regarding staff knowledge of the health effects of extreme heat and the best ways to care for the elderly during very hot weather. Clinical care staff need to be aware of the importance of caring for the elderly in periods of extreme heat, even if air conditioning is available and functioning.

### 4.1.2 Building and maintaining community resilience

Key findings for building and maintaining community resilience:

- Community connectedness and local networks are strong contributors to community resilience and recovery.
- Resilience of community and individuals will be reduced by people leaving a community following an extreme event.
- Inherent levels of vulnerability and how they may change over time will help prioritise adaptation.
- Community service organisations are important in building resilience and addressing community vulnerability.
- Communities will be more likely to accept adaptation solutions as climatic conditions become more severe.

***Community connectedness and local networks are strong contributors to community resilience and recovery.*** Assistance from friends, neighbours and family during a disaster builds a sense of place, which then supports community resilience. Being connected to neighbours and having friends strongly enhances individuals' resilience, even independently of the length of time of residence in the community (Boon et al. 2012D). Apan et al. (2010) also found that in areas vulnerable to flooding, communities with greater connections displayed more resilience. Furthermore, Boon et al. (2012D) noted that "state government services should not dominate or overshadow local government or volunteer roles, but should support and guide local efforts and initiatives" (p. 264).

Stanley et al. (2013D) identified three ingredients for a community to be successfully adapted: community strength; adequate, secure, ongoing financial support to enable the community to do this work; and a climate change and adaptation governance structure that coordinates, enables, promotes and finances a significant part of the adaptation process. Other identified) factors of community resilience include:

- capacity to self-organise
- access to social networks, including family
- collective learning from past experiences
- diversification of markets and employment

(Boon et al. 2012D).

***Resilience of community and individuals will be reduced by people leaving a community following an extreme event.*** The departure of individuals may further decrease the resilience of both the community and the individuals leaving as they are likely to be unfamiliar with local conditions and access to support networks in their new location. The desire to leave was predicted following the 2010/11 Queensland floods, which suggests that decisions are influenced by factors relating to reduced adaptability (including ill health, a poor sense of place, low financial capacity) and experience with infrastructure problems (Boon et al. 2012D). Community members who had received financial support by government or charity groups were also more likely to leave the community, which was consistent with being more financially or emotionally vulnerable, or having sustained extensive damage by the hazard event (Boon et al. 2012D). However, it is also noted that relocation can be considered a form of adaptation, particularly where future climate risks for the location being left are seen as sufficiently high that other adaptive actions may not be perceived as adequate.

***Inherent levels of vulnerability and how they may change over time will help prioritise adaptation.*** Some communities are inherently more vulnerable than others because of their geographical, social, cultural and/or economic situation (Kiem et al. 2010a). Social stratification, particularly wealth inequality, plays a key role in constraining the adaptive capacity of certain communities and individuals, increasing vulnerability (Hanson-Easey et al. 2013D). What has not been well considered in the exploration of adaptation options is how these vulnerabilities may also change over time – particularly with regards to non-climate drivers and factors.

This theory applies to natural systems and human community systems alike. A community that is degraded in habitat and survival options is more inherently vulnerable to changing climatic conditions. For example, adaptation of Australia's natural systems to climate change will be constrained by:

- rates of evolutionary change versus rates of climate change

- reductions of suitable habitat
- limited capacity to migrate due to habitat fragmentation
- extreme events that reduce the capacity of a forest to recover (Boulter 2012).

***Community service organisations are important in building resilience and addressing community vulnerability.*** However, many community service organisations (CSOs) are highly vulnerable to extreme weather events and would face temporary or permanent closure as a result of major damage to physical infrastructure and disruptions to critical services (Mallon et al. 2013D). This closure is likely to occur over periods when there is a critical need for their services to assist clients to respond to and recover from crisis, with many small to medium sized CSOs – and in particular those that provide direct services from an office or building – facing the risk of permanent closure. The follow on impacts for those already most vulnerable to climate risks, some of whom rely on CSOs to help overcome everyday adversity, is likely to be severe (Mallon et al. 2013D). Despite these vulnerabilities and the opportunities for CSOs to improve community resilience, they are mostly overlooked in policy and climate adaptation studies.

***Communities will be more likely to accept adaptation solutions as climatic conditions become more severe.*** Hurlimann and Dolnicar (2011) noted that past experience with drought may make people more resilient and less willing to relocate, a response that is discussed further in Section 4.2. Participants stated they would explore many options before choosing to relocate and would delay relocation for multiple reasons, including social, financial and attachments to place. For example, people prefer the solution of introducing recycled or desalinated water to the drinking water supply – a move that has a high level of public resistance – to being forced to move due to a water shortage.

### 4.1.3 Messaging and communication

Key findings related to messaging and communication in order to increase resilience and adaptive capacity:

- Climate change adaptation terms are often misunderstood or understood differently by different stakeholders.
- Climate change messaging needs to be bespoke to its intended audience and should take care not to induce fear, apathy or scepticism.
- Communication and education about climate change needs to be targeted to vulnerable and hard-to-reach populations (older people, low income groups, people with disabilities, newly arrived migrants and Indigenous communities).
- Collaboration and effective sharing of information is critical.
- The messenger is just as important as the message.

***Climate change adaptation terms are often misunderstood or understood differently by different stakeholders.*** Concepts such as ‘resilience’ tend to be oversimplified by policymaking and planning processes. ‘Resilience’ should not be mistaken for stoicism or ‘bouncing back’ (i.e. returning to a pre-disaster state), as this understanding can actually be a barrier to increasing adaptive capacity by supporting a reluctance to change (Kiem et al. 2010b). Lack of consistent adaptation terminology between organisations will also create issues for cross-jurisdictional communication and cooperation (Hadwen et al. 2011). For example, confusion between ‘mitigation’ and ‘adaptation’ was also identified within the private sector (Johnston et al. 2013D). At the same time, use and definition of key terms need to better take into account socio-economic diversity and allow for more tailored, context-specific responses (Howes et al. 2013D). As some organisations and departments utilise terms differently, this suggests that terms need to be clearly defined and discussed at the outset of planning processes to ensure all participants have the same understanding.

***Climate change messaging needs to be bespoke to its intended audience and should take care not to induce fear, apathy or scepticism.*** While much of the research recommended the need for more communication with communities, this is not without risks. Awareness of climate change can result in a sense of helplessness, thereby reducing adaptive capacity. Climate change knowledge can generate fear and a lack of confidence, as evidenced by residents in Victoria and Queensland concerned about climate change being more inclined to leave a potential climate impacted area (Boon et al. 2012D). This will have resilience repercussions but can also be seen as individuals managing their own risk. It is important that engagement around disaster preparedness strategies do not focus on climate change messages that may induce further scepticism, apathy or fear; messages regarding climate change need to be constructive and positive, focusing on what can be done

and addressing individual interests (Boon et al. 2012D). People can be adaptable without believing that climate change is a concern. This was highlighted in the Ingham, Queensland case study where residents who were least concerned about climate change showed a high level of resilience to floods, likely due to their strong sense of place about their community (Boon et al. 2012D).

Promoting the implementation of adaptation strategies may also give a sense of false security. Therefore, communication of adaptation responses needs to be upfront about its objectives and known limitations. This was particularly noted in response to flood control schemes which were felt to encourage development in high risk areas (Wenger et al. 2012D). The community response to the failure of the Wivenhoe Dam to protect downstream communities during the 2010/11 Queensland floods is a recent example of this phenomenon. The role of the dam for opposing purposes (drought and flood protection) was not well understood (Kiem and Austin 2012). Drought and flooding strategies need to coexist and need to be carefully communicated to surrounding communities, particularly as climate change projections predict that droughts and intense short-lived rainfall events are likely to occur with increased frequency in the future (Sherval and Askew 2012).

Climate change messaging is particularly complex because, as Hanson-Easey et al. (2013D) note, perceptions of climate change do not exist in an isolated vacuum; they are linked with political views, media representations, personal values, lifestyle imperatives and other concerns, such as financial or cost of living issues (Hanson-Easey et al. 2013D). Because of this and climate change's inherent nature as a complex topic with some degree of uncertainty, climate change frequently struggles to hold public attention when competing with other everyday challenges. For climate change to be perceived as a risk that demands a response from individuals and the local community, it must be presented as a serious, present danger to an asset valued by and relevant to the community (Hanson-Easey et al. 2013D). This needs to be carefully balanced with the suggestion by Boon et al. (2012D) to avoid generating fear.

Public engagement on climate change, therefore, cannot simply be improved through educating the 'misinformed' with more accurate information (Hanson-Easey et al. 2013D). Instead, the design and implementation of bespoke, tailored climate change communication and visual narratives are needed that align with a community's interests, concerns, and general worldview. This will also help to avoid audience responses being ineffective or eliciting the opposite reaction from those intended (Hine et al. 2013D). "Climate change will always mean different things to different people, and the opportunities this threat engenders for social dialogue on what is valuable, who is most vulnerable, and what type of future we want for future generations, are considerable" (Hanson-Easey et al. 2013D p.53).

***Communication and education about climate change needs to be targeted to vulnerable and hard to reach populations (older people, low income groups, people with disabilities, newly arrived migrants and Indigenous communities).*** Related to the point above, targeting needs to take into account local and cultural considerations. Research by Reser et al. (2012) shows that people from more closely settled areas with higher levels of education, women and younger generations are more likely to be concerned about climate change, although the gap may be narrowing between rural and urban people (Reser et al. 2012). Boon et al. (2012D) also noted that younger generations are more likely to be concerned about climate change; therefore a focus on disaster education for this age group will help this cohort to adapt to longer-term changes in climate. Older groups, and those less educated have been found to be the least concerned and informed about climate change.

People from culturally and linguistically diverse (CALD) backgrounds can face greater challenges during extreme heatwaves due to socio-economic disadvantage, linguistic barriers, poor housing conditions, and cultural practices (such as heavy clothing or not drinking water). For local and state government, creating refuges (such as community houses), providing sheltered bus stops with drinking water, increasing cultural awareness in health services and other agencies, and building stronger partnerships are additional actions that should also be considered (Hansen et al. 2012D).

Fritze et al. (2009) also note that regarding climate change, hard-to-reach communities may also include wealthy, high consumption communities and people who are sceptical about climate change or the proposed actions to address it. Principles for engaging hard-to-reach communities include devoting time and resources to develop trust, using existing networks and trusted sources of information, and going to places where people feel comfortable.

Carefully designed, well-implemented and effective community engagement strategies are important components of effective and inclusive climate change adaptation measures. Citizen engagement in decisions and actions can have multiple benefits, including but not limited to securing local ownership and support; creating heightened trust, transparency and credibility for decision-making processes; making policies more practical and relevant; and achieving cost savings (Fritze et al. 2009). However, Hansen et al. (2012D) also point out that the identification of vulnerability based on factors that make a group distinct or different to the broader population can

be divisive. The response to vulnerability and how it is communicated should be sensitive to this, and ensure that actions do not reinforce perceptions of difference.

***Collaboration and effective sharing of information is critical.*** Information sharing within agencies, between levels of government and with the community was routinely identified in much of the research as critical to collaboration. Information sharing needs to be planned and strategic, particularly for emergency management which needs to consider operational, tactical and strategic issues.

How to effectively engage stakeholders on adaptation, particularly when change is required, remains a key challenge. QUT (2010, p. 9) notes that:

> The standard approach of making relatively small adjustments to existing management processes is unlikely to be successful. Fundamental shifts in thinking are needed that explicitly acknowledge the new and uncertain risks a changing climate is likely to bring. Processes for bringing together stakeholders and key decision-makers with the scientific community could help promote new forms of dialogue and consensus-building.

Integrated land management (ILM) is one approach being trialled as a technique for stakeholder engagement to enhance the resilience of socio-ecological systems between stakeholders and across multiple scales through major changes in land use. As a process of greater collaboration, this "involves facilitating interactions, sharing knowledge and joint decision-making between different levels of government and between public and private land managers" (Bennett et al. 2012 p. 5). Bennett et al. (2012) have identified numerous enablers for good collaboration including:

- building on existing formal and informal networks
- creating informal links across governance levels to reduce problems associated with imbalances in information and influence
- using existing policies and strategies as a basis for developing common objectives
- carefully considering the nature of change, particularly climatic change.

Collaborative approaches can increase costs in the short term due to the greater time requirements. Collaboration can also be hindered by unequal power relations, fragmentation and lack of leadership in interactions and decision-making.

***The messenger is just as important as the message.*** The perceived importance of each source of communication was found to vary between and within communities (Boon et al. 2012D). This reinforces the need for communications to occur across multiple modes and by different sources, including emerging social media. Research by Boon et al. at (2012D) at locations in Queensland and Victoria found compelling evidence that the community does not trust the government or media with information about climate change but were more inclined to believe scientists. This result parallels the findings of Reser et al. (2012) on public trust in these sources.

#### 4.1.4 Community expectations for government

Key findings for community expectations and government in relation to efforts to increase resilience and adaptive capacity:

- Community expectations about the role of government for climate change adaptation may not align with government responsibilities and capacity.
- Deliberative processes between government and communities can have a positive effect on perceptions of and engagement with climate change adaptation.

***Community expectations about the role of government for climate change adaptation may not align with government responsibilities and capacity.*** Residents in New South Wales and Victoria see a significant role for government in coastal adaptation, including creating knowledge, sharing information, managing risk to public and private assets, local planning and paying for adaptation action (Barnett and Waters 2013D). Participants distinguished adaptation functions by different levels of government, with state government seen as the best entity to coordinate local governments and provide funding support. Federal government was seen as needing to focus on providing risk information and bearing adaptation costs. Local government was viewed as more appropriate for managing public assets, regulating decision-making related to private adaptation and coordinating local planning. Community members were not interested in one level of government or sector having sole responsibility for coastal adaptation. This may also apply to other areas of adaptation action.

***Deliberative processes between government and communities can have a positive effect on perceptions of and engagement with climate change adaptation.*** Hobson and Niemeyer (2011) tested the efficacy of employing deliberative processes – that is, creating opportunities for people to share information and examine an issue together to come to some conclusions about it – to foster adaptive capacity for individuals from the ACT region, compared to just providing climate change information. It was found that the discourse increased motivation, fostered a greater desire for action and willingness to act, and reduced scepticism. Being exposed to different opinions and ideas allowed participants to re-evaluate their own positions and form more coherent positions on the climate issues being discussed (Hobson and Niemeyer 2011). The authors noted that this change in attitude does not necessarily translate to adaptive action and suggest that "strong governance signals and leadership are still essential for fostering a positive public response to the challenges of climate change" (Hobson and Niemeyer 2011, p. 957).

Research by McNamara et al. (2011) in two Torres Strait Island communities also indicated that confidence in decision-making or governance processes is critical in the assessment of limits to adaptation. Confidence in the process underpins perceptions of risk, especially as to if, how and when barriers may be addressed, and provides context in which limits to adaptation can be assessed or determined by a community rather than imposed by external circumstances (McNamara et al. 2011).

## 4.2 Learning from experience

*The findings in this section are particularly relevant for emergency management.*

*"Vows made in storms are forgotten in calm." (Thomas Fuller in Verdon-Kidd et al. 2010)*

Natural disasters are generally considered by governments as one-off events, as evidenced in early drought policy (Sherval and Askew 2012). However, the perception of some climate-related events has been shifting over time. For example, drought was viewed until the late-1980s as a climatic abnormality and therefore was treated with disaster relief policies in a similar way to earthquakes or floods (Botterill and Wilhite 2005, in Kiem and Austin 2012). However, today the view of drought as a "one-off, unpredictable and unmanageable natural disaster" is questioned in science and policy (Kiem and Austin 2012, p. 5).

Regardless, adaptation planning will be informed by lessons learned from past events. They are a valuable source of information with regard to:

- identification of unknown vulnerabilities or those that have yet to be addressed, including different levels of vulnerability within a single community
- adaptation measures put in place as a result of the knowledge gained from the experience before and immediately after the event
- adaptation measures put in place following subsequent reflection or formal enquiry on ways to better prepare for future events
- understanding community, institutional and governance responses to climate events, and their interactions that may determine the success or failure of climate change adaptation strategies (Kiem et al. 2010a).

Recent events (drought, bushfire, floods and storms) have resulted in various policy responses to disaster risk management across the country that has enabled rapid mobilisation of resources which can assist with adaptation planning (Howes et al. 2013D). The lessons below have been informed by research reviewing these events to help inform adaptation decision-making. Broader emergency management responses have not been considered as part of the methodology of this project.

Learning from experience has tended to focus more on these extreme events rather than more gradual changes. There is a risk that adaptation lessons are skewed by only understanding the impacts and responses to extreme events, and opportunities to learn from more gradual changes are missed.

Key findings regarding how past experience with extreme events can inform future adaptation action:

- Prior experience is unpredictable in its influence upon disaster resilience.
- Short-term adaptation responses may create a false sense of security in the longer term.
- Disaster management is a useful starting point from which to consider renewed institutional arrangements for adaptation.
- Basing decisions on past experiences will become increasingly risky.
- We have already begun adapting; however, climate change creates additional complexity and may not be the primary driver of change.
- For some disasters, attitudinal barriers can prohibit planning, and public discourse is needed to change views.
- Local policy that is enacted after an extreme event can become a model for new national policy.
- Extreme climatic events can provide impetus for overdue or unpopular adaptation options.

***Prior experience is unpredictable in its influence upon disaster resilience*** (Boon et al. 2012D). Research in Innisfail (post-cyclone) and Ingham (post-flood) found that preparedness was highly predicted by prior disaster experiences, as well as financial capacity and communications. Of note was the finding that homeowners in Innisfail and Ingham did not report having building insurance despite past experience.

Kiem et al. (2010b) noted that lack of system stresses, such as water scarcity, is likely to make communities unprepared for system failures. Communities with a collective memory of a water supply crisis may be capable of responding to water insecurity with adaptive change more easily than those that lack experience.

AECOM (2010) identified that there was a high level of awareness of bushfire in the ACT due to relatively recent and historical bushfire events. This level of awareness can be observed through bushfire preparedness strategies being implemented (including gutter and garden design in some new developments), and is supported and driven by the high quality and highly accessible data on bushfire in the region (AECOM 2010).

However, preparedness for one disaster can make residents and agencies less concerned or prepared for other potential risks. For example, Victoria's drought prior to the 2010/2011 floods had caused many residents to become apathetic towards flooding. Residents were more concerned about drought-proofing their homes and some were seeking permits to build on properties covered by flood overlays (Bird et al. 2011). A few residents also thought they were safe because their home was built above 1909 flood levels. Similarly, Victoria's Department of Health had made progress in pre-planning prior to the 2009 heatwave; however, the department was still challenged by service demands and escalating fatalities during the heatwave (QUT 2010). Bushfire risk planning had taken precedence over planning for extreme heat.

On the Gold Coast, significant coastal protection works and legislation was enacted following repeated storm surge events during the 1960s and 1970s. However, an extended period of relative calm (or limited storm surge events) followed, causing lessons to be forgotten and governments to be less proactive. At the same time, significant development has occurred. While the management and protection responses undertaken have been effective to date, many of its elements have yet to be tested under extreme conditions. Proactive responses are also facing increasing community objections during calm weather (Helman et al. 2010).

***Short-term adaptation responses may create a false sense of security in the longer term.*** The building of resilience, such as diversifying water supply systems, needs to consider long-term viability and sustainability. Current actions may create a false sense of security within individuals and communities and thereby reduce long-term resilience (Albrecht et al. 2010). For example, Kalgoorlie, with the provision of the Golden Pipeline to supplement local water supply with that from Perth, have much greater confidence that their water supply will persist into the future due to technology and government support than communities such as Broken Hill (NSW), that have had to endure repeated failure of their water supply. However, Kalgoorlie's water supply is potentially at risk due to climate change and residents may find themselves unprepared for a future of price increases and interruption of supply (Albrecht et al. 2010).

***Disaster management is a useful starting point from which to consider renewed institutional arrangements for adaptation.*** In Australia, disaster management arrangements are formed around interagency and intergovernmental approaches spanning all three levels of government, working together closely with volunteers, NGOs, businesses and the community. Importantly, issues around key definitions have been largely overcome. (Howes et al. 2013D).

***Basing decisions on past experiences will become increasingly risky.*** There is a tendency to stay within known parameters and uncertainties, yet there is a growing need to understand system-wide properties at scales and within timeframes beyond the normal comfort zone of most decision-makers (Albrecht et al. 2010).

Small changes in the sequencing, timing or location of impacts from specific events should be used to hypothesise a number of 'what if' scenarios to consider potentially different or more significant impacts (Verdon-Kidd et al. 2010). Impacts on overall capacity of core services, such as health care and social services, should also be included (e.g. longer-term disasters, multiple disasters across a region or multiple events over short periods of time). The 2009 extreme heatwave and bushfires had major impacts for Victoria's infrastructure, emergency service providers and health care system. The electricity system has been identified as being particularly vulnerable; as it operates with little spare capacity, it lacks resilience to unexpected events such as a heatwave. Scenario testing is also recommended to analyse the impact of hotter and more prolonged heatwave events on Victoria's infrastructure (QUT 2010).

***We have already begun adapting; however, climate change creates additional complexity and may not have been the primary driver of change.*** Major events such as cyclones, bushfires and floods have been a major impetus to undertake adaptation measures (Kiem et al. 2010a). These events have resulted in various changes, including:

- introduction of building and infrastructure design standards
- emergency management protocols
- revised coastal policy
- land buybacks and exit grants
- changes in water policy, including the introduction of water trading
- technological and engineering-based solutions (such as desalination and flood protection works)
- community awareness programs (including warning systems and pre-event preparation)
- changes to coordination, operation and maintenance of essential infrastructure (e.g. drainage networks and load shedding).

However, measures implemented after these events may not be fit for purpose with continued climate change. For example, flood protection was put in place to address risk in Charleville (Qld) from the Warrego River but failed to take into account flooding from Bradley's Gully; this left the town exposed to flooding as evidenced in 2008 (Kiem et al. 2010a). In NSW, the residents of Broken Hill have faced numerous water crises and have implemented various engineering strategies to improve the water catchment and supply systems. However, a hotter climate and harsh cost-recovery economic conditions put the security of Broken Hill's future at risk (Albrecht et al. 2010).

*Flood protection was put in place to address risk in Charleville, Qld, from the Warrego River but failed to take into account flooding from Bradley's Gully; this left the town exposed to flooding as evidenced in 2008 (Kiem et al. 2010a).*

***For some disasters, attitudinal barriers can prohibit planning, and public discourse is needed to change views.*** During Victoria's 2009 heatwave, there was a general attitude among certain agencies that heatwaves do not require a specific planned response or that a generic disaster response is adequate (QUT 2010). Furthermore, there is a collective attitude among the public that as Australia is a country where warm temperatures are common, excessive heat is not a threat. Public education campaigns are recommended (QUT 2010). However, the issue of response is compounded by the fact that the heatwaves are not a recognised emergency by the federal government; therefore, state governments are unable to claim reimbursement for a percentage of certain response and recovery costs.

***Local policy that is enacted after an extreme event can become a model for new national policy.*** Cyclone Tracy's high intensity and low movement speed caused widespread devastation due to Darwin's inadequate structural engineering design, including the complete destruction of around 60 per cent of housing which led to the evacuation of around 80 per cent of Darwin residents (Mason and Haynes 2010). Following the disaster,

design recommendations were produced in response to the failures of building practices by incorporating integrated engineering design into residential buildings (Mason and Haynes 2010). These wind engineering recommendations and design standards have since been refined and incorporated into national building codes for other cyclone prone areas of Australia. The practice of using structural engineering design in housing is now standard in Australia (Mason and Haynes 2010).

Queensland's Floods Commission of Enquiry made a broad range of recommendations, including actions to improve disaster preparedness, infrastructure resilience, public education, and policy and regulation. In its response, the Queensland Government expressed support for all recommendations and established a framework for implementation, including the creation of five implementation groups:

- Planning Implementation Group
- Building Implementation Group
- Environment and Mines Implementation Group
- Emergency Management Implementation Group
- Dams Implementation Group

(DEWS 2013).

While the response to the Queensland floods has been tailored to the specific circumstances of the state and the needs of Queensland communities, the research suggests that the responses and policy actions taken in response to this natural disaster have the potential to influence and lead disaster management responses across the country.

***Extreme climatic events can provide impetus for overdue or unpopular adaptation options.*** Kiem et al. (2010b) note the ability of natural disasters to provide drive for governments, communities and industry to implement adaptation measures that may not be popular or deemed worthwhile during periods of average climate. Engineering-based design requirements for residential buildings in tropical cyclone regions were implemented in response to Cyclone Tracy. Because these changes were mandated, the process of incorporating these requirements became progressively more affordable (Mason and Haynes 2010).

## 4.3 Costing, financing and funding adaptation

There are considerable challenges associated with costing, financing and funding adaptation actions. Adaptation options entail varying costs, in terms of time and resources involved in their implementation and maintenance, and with respect to the risks involved (Hadwen et al. 2011). Robust costing must take into account a wide range of direct and indirect impacts of both climate change itself and the responses put in place. The effectiveness of some options may decrease as climate change continues or as other factors that modify the impact change. Consideration of who pays for adaptation is also an ongoing issue for many decision-makers.

Key findings regarding how to cost, finance and fund adaptation action:

- The return on adaptation needs to be considered beyond the short term.
- Adaptation options can have distinctly different thresholds of or criteria for appraisal.
- There is limited research testing how adaptation costs and benefits might be distributed through the community and over time.
- Disaster relief is not currently an effective tool for financing adaptation.
- Traditional economic approaches and existing policy mechanisms can create barriers to effective adaptation decisions, particularly in the private sector.
- Current insurance products and practices need improvement to be effective adaptation tools in the longer term.

***The return on adaptation needs to be considered beyond the short term.*** Planned retreat along the coast is likely to have the highest upfront cost, but there can be a high return on investment due to the potential for greatly reduced costs associated with future extreme events and inundation, at least in regional or rural areas (Hadwen et al. 2011). In higher density urban coastal areas, retreat is often not viable due to the high value of coastal assets and areas compared to the costs of increased flooding

*In working with three local governments in Queensland, Fleming et al. (2010b) found that different coastal adaptation options (protect, accommodate and*

from sea level, storm surge and extreme rainfall flooding. Retreat pathways require parallel legal and social frameworks to cover future retreat and associated transitions (Helman et al. 2010).

***Adaptation options can have distinctly different thresholds of or criteria for appraisal.*** In working with three local governments in Queensland, Fletcher et al. (2013D) found that different coastal adaptation options (protect, accommodate and retreat) have distinctive acceptance thresholds with decision-makers. Intensification of defensive structures (protect) is primarily based on economic or cost-effectiveness thresholds, whereas retreat is predicted more on political or social thresholds conditioned by the local perceptions of acceptable risk by residents in vulnerable locations.

***There is limited research testing how adaptation costs and benefits might be distributed through the community and over time.*** The costs per property of implementing community-level adaptation options are likely to be reduced as requirements are introduced and homes are increasingly built from standardised plans (Mason and Haynes 2010). Some situations will require alternative adaptation options, either at the property level or alternative funding from scales of governance beyond the community; regardless, benefits may not be shared equally across the community (Fletcher et al. 2013D). Economic tools that estimate specific costs and potential benefits throughout the community can help inform sensible choices about which adaptations or suites of adaptations are likely to yield more benefits than they cost to implement (Fletcher et al. 2013D). Such information will be essential to engage communities in adaptation. Community-level coastal adaptation options, such as seawalls, have the potential to yield a good mix of total benefits and high benefit-to-cost ratios; they also require coordination and funding from the entire community for reasons of both equity and affordability. Going beyond traditional local and regional scale cost–benefit analyses to investigate the distributions of costs and benefits within the community will be vital for ensuring the most efficient adaptation options that are equitable, affordable and economic (Fletcher et al. 2013D).

Draft research by Dobes et al. (2012D) examined the Cairns community's willingness to pay for post-cyclone emergency services. This work identified that the community was generally willing to pay for a faster resupply of fresh food and a reconnection of utilities but not for additional services (policing and emergency accommodation for animals). Despite a willingness to pay, faster provision of services may not be feasible due to post-cyclone logistical challenges. The value of these services may need further consideration, especially given that these issues are already being addressed by competition in the private sector. It also would be difficult to restrict faster utility connections only to those willing to pay; all residents in a re-connection area would benefit, incentivising many to free ride.

***Disaster relief is not currently an effective tool for financing adaptation.*** Combined underinvestment in protection prior to a catastrophic event and taxpayers financing recovery following the event has been critiqued on both efficiency and equity grounds (Crompton et al. 2012D). Disaster relief in response to the 2010/11 floods in Victoria and Queensland was felt by many to be over-generous and untargeted, and under current arrangements would not increase resilience to disaster and adaptation in the longer term (Wenger et al. 2012D). Regardless, with continued climate change, the long-term viability and suitability of existing relief arrangements for natural disasters is questionable. Existing funding mechanisms, such as funding arrangements for Natural Disaster Recovery Relief Arrangements (NDRRA), provide for the repair of public infrastructure within a short period of time (e.g. 21 days) from the date of declaration of the natural disaster. Councils may not be able to commence emergency works and clean up within this time frame. While extensions have been granted (e.g. the Newcastle floods of 2007), this is by exception (Verdon-Kidd et al. 2010).

Reducing reliance on government emergency relief may help defer the costs of subsidies while promoting more strategic adaptive behaviours (Boon et al. 2012D). The *Darwin Cyclone Damage Compensation Act 1975* allowed uninsured owners and occupants to claim up to half of the value of their home and contents (capped) from the government. Mason and Haynes (2010) identify that because the payments were not means tested, this can be seen as having a disincentive for people to cover their own exposure.

***Traditional economic approaches and existing policy mechanisms can create barriers to effective adaptation decisions, particularly in the private sector.*** Communities may not have the capacity to invest in adaptation due to financial constraints or because of lack of consensus (Fletcher et al. 2013D). The level of government and community support will guide adaptation decision-making as much as the cost of the options themselves (King et al. 2012D). The types of adaptation will also be bound by the scale at which adaptation options are governed, which may further constrain funding or financing opportunities (Fletcher et al. 2013D).

Hussey et al. (2013D) note that there are currently no market-based mechanisms to encourage financing adaptation in physical assets and infrastructure. There are also institutional and policy barriers, including a lack of policy incentives to replace or upgrade existing assets to increase climate resilience (Hussey et al. 2013D). For the private sector, Johnston et al. (2013D) identify uncertainty in policy and information, as well as insufficient commercial incentives as a problem for engagement with this sector in general. A combination of information

provision, non-coercive adaptation financing policy such as co-financing and market-based mechanisms (tax-credits, grants, tariffs, climate bond, etc.), coercive regulation by requiring adaptation, and the introduction of specific taxations are recommended by Hussey et al. (2013D) to facilitate private sector adaptation action.

The long-term protection of physical and financial assets of Australia will also require significantly more capital than is available through normal funding options. It is suggested that further adaptation policy and reform include business cases for private investment and financing (Hussey et al. 2013D). Kiem et al. (2010a) note that "power utilities and transport (especially rail) companies find it difficult to invest in adaptation because of regulatory barriers (they are unable to recoup their investments through pricing, for example) – limiting their potential to enhance their adaptive capacity" (p. 34).

Risk information is also needed to trigger private adaptation responses. Johnston et al. (2013D) identify that there is a paradigm in many governments, including those in Australia, that adaptation in the private sector will be predominantly led by market signals; however, it is suggested that without direct policy guiding adaptation, this is a high risk strategy which is untested.

***Current insurance products and practices need improvement to be effective adaptation tools in the longer term.*** Insurance is generally considered an important adaptation tool to help defray the costs of climate change impacts, particularly in the private sector. However, there are limitations associated with insurance arrangements, individual behaviours and government responses to natural disasters. As noted in one report, 26 per cent of all NSW households do not have any form of home and contents insurance (Giles 2007 in Verdon-Kidd et al. 2010, p. 44).

Insurance plays a key role in sending price signals that reflect risk and contributes to resilience by supporting recovery from extreme events. While there is growing scientific confidence that many natural hazards will increase in both frequency and intensity, regional and local implications of a warming climate on extreme weather remain uncertain. As a result there is no clear climate change signal in the increasing cost of disasters (Crompton et al. 2012D). The 2013 flooding in Queensland may be the start of such a signal, as insurance providers are in the process of withdrawing from high risk areas or significantly increasing premium prices.

Insurance coverage can be linked to prior experience but is more likely associated with financial capacity. The provision of government or charitable assistance has been found to be negatively associated with insurance cover in some flood- and fire-impacted communities (Boon et al. 2012D). Limited or patchy uptake of insurance by individuals will limit the effectiveness of insurance as an adaptation response. Consumers are reluctant to pay for insurance to cover natural hazards with low probabilities of occurrence, as evidenced through surveys with 2011 Australian flood victims (Crompton et al. 2012D). Furthermore, post-disaster inflation, a surge in demand and shortage of materials and labour can leave fully insured asset owners with significant costs. Many Darwin residents found that after Cyclone Tracy they were left with significant out-of-pocket expenses for their fully insured houses due to post-disaster inflation, which was compounded by Darwin's relative isolation (Mason and Haynes 2010).

Limited investment in protection and preparation for natural disasters combined with government financing of part of the recovery can be critiqued on both efficiency and equity grounds (Crompton et al. 2012D). There are critical issues of equity when examining preparedness for disaster, since people with limited means are likely to be more vulnerable to impacts and hence will be subject to those influences which lead to leaving a community. In addition, they are more likely to be subject to greater psychological distress, and have poor coping and adaptive capacity as a result, bringing an additional burden upon community service organisations, including government agencies (Boon et al. 2012D).

Government has a key role to play in better supporting uptake of insurance by residents and businesses and by seeking to minimise future losses through land use planning and building regulations (Crompton et al. 2012D). Greater consideration by state and federal government to actively support the uptake of insurance, including subsidies for lower socio-economic groups needs should also be considered. Government should also consider how to work with industry to promote awareness about standard insurance arrangements regarding coverage. For example, although insurance companies cover the cost of repairs to property damage associated with landslip, they do not generally cover restoration works associated with the landslip itself. Similarly, the cost of removing a fallen tree is also not covered by insurance unless it has fallen on a fence or other insured object (Verdon-Kidd et al. 2010).

## 4.4 Limits and barriers to adaptation

There are many challenges associated with adaptation. Understanding the limits of and potential barriers to adaptation is important for decision-making for a number of reasons, including:

- determining which responses to climate change are both practicable and legitimate, and the timescales over which adaptation may be needed and considered effective
- engaging with stakeholders to identify issues and values
- prioritising adaptation strategies and refining their objectives (Morrison and Pickering 2011).

Social and economic limits to adaptation are largely subjective, and as opinions and situations can change, these limits are rarely absolute or insurmountable. However, the mental and physical limits of individuals and many species remain largely unknown. The factors that create limits and barriers are also strongly interrelated and complex, making it difficult to isolate a particular ecological, economic or institutional system as the key factor limiting adaptation (Evans et al. 2011).

Key findings regarding the limits and barriers to adaptation:

- Lack of community support can be a significant barrier to climate change adaptation.
- Local governments face capacity and resource constraints to effectively support local adaptation.
- Top-down, state-driven policy practices may inhibit local policymakers from being able to push forward local policy initiatives.
- Current institutional arrangements can create barriers for effective collaboration.
- Perceptions of adaptation interventions will vary between stakeholders and may be a source of conflict.
- Lack of system understanding remains a key barrier to adaptation.
- Lack of accessibility to the most up-to-date and relevant information can be a limitation for decision-makers.
- Key tools to support adaptation are constrained by potential issues of liability.
- Failure to consider the potential consequences of climate change in formal reviews of natural disasters is constraining adaptation learning.

***Lack of community support can be a significant barrier to climate change adaptation.*** As evidenced by multiple failed efforts to introduce potable wastewater reuse to supplement failing water supplies, community support for adaptation options is critical (Poloczanska et al. 2012). Similarly, relocation from areas at higher risk from storm surge in Darwin was proposed by the federal government after Cyclone Tracy. This strategy was met with public opposition and eventually abandoned, despite the likely risk of future storm surges (Haynes et al. 2011).

Effective communication has been identified as key to ensuring community engagement for implementing waste and recycled water use for a case study in Queensland. (Freeman, Bates et al. 2008 in Poloczanska et al. 2012). Alternatively, poor communication, combined with top-down management approaches can lead to a disconnect between policy and the communities affected by adaptation strategies.

***Local governments face capacity and resource constraints to effectively support local adaptation.*** Local governments in all states and territories face competing priorities and limited resources when addressing adaptation (Mukheibir et al. 2012). However, long-term, large adaptation projects are likely to be beyond the capabilities of most local governments and need federal funding on a priority basis. The complexity and cross-cutting nature of climate change risks, particularly of coastal areas, requires inter-jurisdictional reform supported by a national coastal policy that clearly articulates roles and responsibilities (Helman et al. 2010).

***Top-down, state-driven policy practices may inhibit local policymakers from being able to push forward local policy initiatives***. Kellett et al. (2011) have considered the use of climate analogues to help identify potential policies for any given region under a new climate. Using this approach in three states (Queensland, Western Australia and South Australia), the found no discernibly clear pattern for the use of analogues at the policy level. This is largely because many relevant policies, particularly those related to planning and health, are driven at the state level. Many local councils, especially in South Australia, expressed frustration that the state-wide framework and directives did not take into account local circumstances (Kellett et al. 2011). In NSW, coastal planning local adaptation strategies have been seen as being constrained by state and federal legislation (Hadwen et al. 2011). The lack of articulation and clarity about the roles and responsibilities of various levels of government and other entities were also identified as a limiting factor, particularly for existing development and infrastructure (Verdon-Kidd et al. 2010). This was noted with regards to flooding but also more generally by the

mining and resources sector (Sharma et al. 2013). In Queensland, application of planning legislation and instruments to address flood are also significantly compromised by exemptions. This includes mining and agriculture activities, and some aspects of the electricity supply network. State Planning Policy (SPP) 1/03 requires community infrastructure to function effectively during and after a flood of a specified flood risk level; however, some community infrastructure, including childcare, aged care, schools and electricity works, is not required to meet these standards (Wenger et al. 2012D).

Examples were also identified where local policies, regulations and operating rules imposed adaptation barriers. For example, cold water releases are specifically avoided in some rules of operation for reservoirs, and planning regulations may restrict the creation of new urban water bodies, such as wetlands, in areas where current wetlands have management issues affecting local amenity (such as mosquitos and algal blooms) (Robson et al. 2013D).

***Current institutional arrangements can create barriers for effective collaboration.*** Planning, building and insuring are co-dependent elements of the built environment; however, there is relatively little transfer of expert personnel between professions. This lack of interaction is compounded by the governance of these issues by the government departments, statutory bodies and boards that have responsibility for current guidelines, codes and legislation (King et al. 2012D).

The timing required to amend legislative frameworks can also create barriers to adaptation. This was explored by Hussey et al. (2013D) for the integration of revised flood data and climate change information into planning schemes. Barriers identified include “a ten-year interval before some planning instruments become due for revision, the complexity of approval processes, cost, compensation liabilities and competing pressures” (Hussey et al. 2013D p. 63).

**Perceptions of adaptation interventions will vary between stakeholders and may be a source of conflict.** Adaptation interventions will be viewed in different ways by different stakeholders and may affect stakeholders differently: “A benefit to one part of the system (such as maintenance of water level) results in a negative impact to another part of the system, with the emergence of winners and losers being one outcome” (Gross et al. 2011 p. 77). This can divide communities, erode trust, and reduce capacity for stakeholders to work together.

Research by Morrison and Pickering (2011) on limits to adaptation in the Australian Alps worked with tourism operators and conservation managers to identify the value of better consideration of social and governance issues in adaptation planning. This approach identified that conflict may arise between stakeholders as a result of different adaptation actions where objectives are not shared. Perceptions of limits were also identified; for example, stakeholders other than tourism operators identified technological and resource limits for ski operators, but these were not identified by the operators themselves.

Limits for one stakeholder can be viewed as opportunities by a different stakeholder. Evans et al. (2011) sought to identify potential limits to adaptation for the tourism and fisheries sector in the Great Barrier Reef Marine Park Heritage Area. In the Great Barrier Reef region, there are many examples where addressing limits to adaptation could benefit multiple industries simultaneously, particularly with regard to catchment management and coastal development, although there may be trade-offs for individual landowners (Evans et al. 2011).

***Lack of system understanding remains a key barrier to adaptation.*** Unknown thresholds of ecological resilience and lack of understanding about the interconnectivity within ecosystems limit the identification of effective adaptation options. Similarly, better understanding of how climatic and non-climatic changes over time will influence vulnerability and adaptive capacity (Hadwen et al. 2011).

Hadwen et al. (2011) identify that the separation of the terrestrial and marine zones in coastal ecosystems limits the understanding of the system’s interconnectedness, affects the accuracy of data produced, and influences policy – often encouraging the zones to be addressed as discrete elements.

Trade-offs between different adaptive management approaches also need to be considered in the short and long term. For example, water managers need to consider a range of short- and longer-term solutions, including diversification of supply and storage options, increasing storage capacity and improving water management through changed behaviours. Some of these responses have the potential to push systems to unstable states with limited predictive capacity, meaning that further adaptive responses will be difficult (Albrecht et al. 2010).

As the greatest need for adaptation may not relate to direct impact or a core function, systems level thinking from a local perspective should also be considered. For example, initial adaptation planning for ports has been focused on the seaward side of operations (access, mooring, loading and unloading of ships); however, it is more likely that disruptions to supply chains and supporting infrastructure have experienced the greatest impacts during recent extreme events, suggesting that planning also needs to be look beyond the port (McEvoy and Mullett 2013).

***Lack of accessibility to the most up-to-date and relevant information can be a limitation for decision-makers.*** The need for increased sharing of information and data is identified as necessary for effective decision-making, including specific and general data relating to climate projections, natural, constructed and social systems, and bio- or geo-physical parameters (Hadwen et al. 2011). There is a distinct lack of coordination of existing databases and data-sharing arrangements between relevant authorities.

***Key tools to support adaptation are constrained by potential issues of liability.*** While the need for information relating to the location of possible risks to support adaptation planning is clear, there is a reluctance to provide this information because of the potential adverse impacts on property values (Wenger et al. 2012D). Furthermore, local and state government planning agencies can be excessively risk averse out of fear of having to compensate people affected by climate hazards (Macintosh et al. 2013D). Formal enquiries following flood events, such as Royal Commissions, are similarly cautious about recommendations for structural measures and were limited to considering options that only protect current development (Wenger et al. 2012D).

Liability shield instruments are one mechanism to reduce this constraint; they provide partial or full exemption from legal liability for action, or lack of action, regarding climate hazards (Macintosh et al. 2013D). Another approach is the use of statutory exemptions, which can provide councils with exemption from liability provided they can demonstrate compliance with applicable codes, guidelines, manuals or demonstrate good faith (Macintosh et al. 2013D).

***Failure to consider the potential consequences of climate change in formal reviews of natural disasters is constraining adaptation learning.*** A review of four recent enquiries on flooding found that they all but ignored the issue of enhanced flooding as a result of climate change and therefore have likely underestimated future risks and adaptation needs. In addition, failure to consider other relevant changes, such as future population pressures and movements, compound this underestimation (Wenger et al. 2012D).

## 4.5 Maladaptation

Adaptation-related decisions intended to reduce climate change impacts may instead increase vulnerability. This problem of increasing risks as a result of adaptation is often termed ‘maladaptation’. Actions that (relative to alternatives) increase greenhouse gas emissions, disproportionately burden the most vulnerable, have high opportunity costs, reduce incentives to adapt, or establish mechanisms that limit the choices available to future generations are maladaptive (Barnett and O’Neill 2010). Adaptation planning decisions should be screened for these possible adverse effects.

Key findings regarding maladaptation:

- Underestimating connections and interdependencies in systems can lead to maladaptation through unintended consequences.
- The management of evacuation due to extreme weather events can be maladaptive if not handed sensitively, leading to inequities and additional problems after the event.

***Underestimating connections and interdependencies in systems can lead to maladaptation through unintended consequences.*** This is explored by Hadwen et al. (2011) in the context of coastal ecosystem adaptation strategies, which mostly contain no overt consideration of flow-on effects in neighbouring habitats. It is critical to the success of adaptation activities that the connectivity between ecosystem and human systems is considered within the decision-making process to make certain non-target habitats are not adversely affected. It was also noted that most coastal adaptation strategies partially take an interdependency approach as they rely on removing or reducing non-climate risks, such as invasive species; these actions can be perceived as adaptation strategies as they address ecosystem resilience (Hadwen et al. 2011).

***The management of evacuation due to extreme weather events can be maladaptive if not handed sensitively, leading to inequities and additional problems after the event.*** The evacuation of Darwin under Cyclone Tracy was enacted under a protocol that prioritised the evacuation of women, children and elderly couples; this split families in some instances, creating disconnected families and communities (Haynes et al. 2011). The negative impacts of the cyclone on mental, physical and social recovery were also observed to be more severe for people who were evacuated (especially non-returned

*The failure of the installed water supply infrastructure on the Torres Strait Island of Erub is one example of an adaptation option gone maladaptive in that it has not remedied the water security issues and may have exacerbated it to some degree by increasing water demand and removing personal responsibility for water conservation (McNamara et al 2011).*

evacuees) than those who stayed. This is explored in Haynes et al. (2011) through the lens of being part of the 'therapeutic community', with those who stayed being able to contribute to the clean-up, rebuilding and reinvigoration efforts. However, it is not known whether evacuees' recovery was hindered by evacuation itself or by the degree of loss experienced by this group; it is also possible that this group may have experienced even greater trauma had they remained in Darwin (Haynes et al. 2011).

## 4.6 Timing and scale of adaptation

The timing for and scale at which adaptation is best delivered remain two fundamental issues. Adaptation will continue to be a series of reactions to environmental and social changes, some quickly executed in response to emergency, others more autonomously in response to slowly changing social and economic conditions. (Gross et al. 2011). Government and communities have tended to favour short-term and responsive approaches, which can make adaptation more difficult to initiate (Stanley et al. 2013D).

Key findings regarding the timing and scale of adaptation:

- Timing of stakeholder engagement needs to be carefully considered.
- Timing and scale of implementation is complex and may not align with financial capacity.
- Adaptation actions need to take a long-term view to be effective.
- Doing nothing may be an appropriate adaptation response.
- Triggers need to be established for extreme events, as do thresholds for when extreme events move from a natural disaster to normal climate.
- Government needs to consider the time and steps it takes to effectively implement adaptation actions.
- Windows of adaptation opportunity following extreme events are short.
- The scale of both the impact and the potential adaptation response need to align.

***Timing of stakeholder engagement needs to be carefully considered.*** Engaging with stakeholders about adaptation to longer-term changes in climate should be considered independently of extreme events when public emotions and political considerations are heightened. Conversely, there is value in capturing learning from extreme events before collective memory fades. Firsthand exposure to climate change–related risks can create an emotional connection to climate change and make it a more meaningful, pressing issue (Hanson-Easey et al. 2013D). However, previous experience with a climate hazard does not necessarily increase ability to respond or adapt.

***Timing and scale of implementation is complex and may not align with financial capacity.*** Understanding when to respond to adaptation and the scale of this response is a critical and challenging question for policymakers. When the answer of when and how to respond is clear from an economic perspective (based on a cost–benefit analysis), the distribution of risk and the distribution of cost may complicate the issue (Fletcher et al. 2013D). Furthermore, communities may not have the financial capacity to fund the recommended adaptation option, such as a seawall, in the short or medium term even if it is economically justifiable and provides broad, equitable benefit to the community. This will put the onus of adaptation in the short term on alternative options, such as individual adaptations funded by the property owner, often at a smaller scale (Fletcher et al. 2013D).

***Adaptation actions need to take a long-term view to be effective.*** Although adaptation decisions need to be made now and adaptation measures need to start being implemented, the timeframe that these options need to take into account is long term to ensure they are effective and do not decrease long-term adaptive capacity (Hadwen et al. 2011). Having more flexible and dynamic policy and planning that looks beyond political cycles is needed for this forward thinking approach.

***Doing nothing may be an appropriate adaptation response.*** Garnett et al. (2012D) state that a do-nothing approach can be considered an appropriate response to climate change risks. However, in order to select this approach, the following are essential:

- full consideration of the potential consequences
- ongoing monitoring of climate change risks
- flexibility to recognise and respond to changed circumstances in a timely manner.

***Triggers need to be established for extreme events, as do thresholds for when extreme events move from a natural disaster to normal climate.*** Governments, hospitals, emergency response organisations and the community were under-prepared for the 2009 heatwave experienced in Victoria (Kiem et al. 2010a; QUT 2010); coping was said to be "the result of reactive competence and capacity rather than proactive planning" (Kiem et al. 2010a p. 33). Part of the reason for this was that, as the event developed over a number of days, there was no clear threshold to trigger the management as a disaster (Kiem et al. 2010a).

The increasing frequency of climate-related events is also changing the perception of what is an extreme and what is 'normal climate' (Kiem et al. 2010a). In light of this, disaster management arrangements may need to be further reviewed. This is typified by changes in drought policy responses in Australia over the past 20 years. The perception of drought has been shifting over time. Drought was viewed until the late-1980s as a climatic abnormality and therefore was treated with disaster relief policies in a similar way to earthquakes or floods (Botterill and Wilhite 2005, in Kiem and Austin 2012). However, today the view of drought as a "one-off, unpredictable and unmanageable natural disaster" is questioned in science and policy (Kiem and Austin 2012, p. 5). Drought measures are moving from a crisis management approach to risk management.

***Government needs to consider the time and steps it takes to effectively implement adaptation actions.*** A sequence of action necessary to enable adaptation needs to occur. First, there needs to be a focus on governance in order to define roles and responsibilities among levels of government and between sectors. Next, statements of purpose and other institutional preconditions are needed in order for government and sectoral players to take action. Finally, after this statutory support is in place, uncertainty about risks and responses as well as an assessment of resources can be addressed. To support this, government initially needs to play an active role in adaptation rather than leaving action up to individuals and sectors (Barnett and Waters 2013D).

***Windows of adaptation opportunity following extreme events are short.*** Recovery from extreme events and other reactive responses create windows of adaptation opportunities with the goal of reducing the impact. Rapid recovery may hinder adaptation, as new knowledge can take time to incorporate into existing regulations and guidelines (e.g. revised building codes). However, there is a need to act quickly, not just for community recovery, but also while the issue is relevant within the community memory and before complacency sets in, which happens relatively quickly (Helman et al. 2010). Delay of implementation of adaptation strategies, particularly after an extreme event, can be detrimental to success (Kiem et al. 2010a).

Conflict can arise when the timing of adaptation objectives differs between stakeholders. Morrison and Pickering (2011) note that effective long-term conservation management goals (usually 10+ years) can often conflict with the short-term decision-making by the tourism industry and political decision-makers (usually less than five years). Rapid recovery responses may over-ride longer-term goals and reduce opportunities for stakeholder engagement.

Other temporal factors will also influence adaptation timing needs. For example, environmental goals of adaptation strategies for natural resource management will vary depending on the climate conditions each year (Lukasiewicz et al. 2013D). During dry years, habitat and ecosystem protection will likely be the primary goals, whereas in wet years the focus would be biodiversity enhancement and restoration.

***The scale of both the impact and the potential adaptation response need to align.*** Climate change adaptation actions should be implemented at local or regional scales, as these scales will determine which adaptation approaches are appropriate in order to address adaptation objectives given the physical, ecological, social, economic and cultural features of the area of concern. However, larger scales require consideration since adaptation actions may have consequences for connectivity with ecological and human systems beyond this area (Hadwen et al. 2011).

## 4.7 Sector-specific findings

A primary purpose of this synthesis was to look across sectors and to integrate and aggregate findings into common threads or themes of learning. This is particularly important in adaptation as responding to climate change largely requires a holistic, systems approach to avoid maladaptation and to manage risks (including non-climatic threats) over the long term. Sector-related messages are relayed, for this reason, throughout this report under broader, interconnected themes. However, as summarised in this section, quite often the research did directly address the adaptation objectives of a specific sector, particularly for natural resource management, primary production and land use planning. It is also important to note that the findings captured below represent the lessons relevant to a sector, but in no way did the research reviewed comprehensively cover any individual sector.

### 4.7.1 Natural environment

Key findings related to adaptation and natural resource management:

- Existing management strategies will lessen the impacts on ecosystems, but the objectives and approaches of conservation and management plans may need to be reconsidered in the context of longer-term climate change.
- Adaptation needs to take an ecosystem-based approach where resources are considered and directed towards a suite of actions; however, this approach is constrained by institutional complexity.
- Taking an ecosystem-based approach to adaptation for natural resource management requires adaptive management, meaning actively experimenting with actions and learning from past activities.
- Due to competing demands and pressures on environmental assets, adaptation needs to ensure diverse stakeholder engagement and collaboration to allow value-based decision-making.
- Habitat protection is considered the optimal action for assisting the majority of species adapt to climate change within the budgetary limitations.
- There are conflicting research conclusions regarding whether water pricing is effective in curbing water demand.

***Existing management strategies will lessen the impacts on ecosystems, but the objectives and approaches of conservation and management plans may need to be reconsidered in the context of longer-term climate change.*** Many adaptation options already occur in response to stresses other than climate change, including protecting and maintaining habitats, landscape connectivity, species management and population genetics (Lukasiewicz et al. 2013D; Garnett et al. 2012D; Hadwen et al. 2011). These options are also likely to have less potential for maladaptation, offer multiple ecosystem service benefits and have lower risk levels. More interventionist approaches need to be considered for maladaptation potential, ecosystem service benefits and effectiveness (Lukasiewicz et al. 2013D).

A review by Hadwen et al. (2011) of existing management actions in Kakadu National Park found that they were considered to be reasonably robust to threats posed by climate change as a consequence of their focus on sustainability and building resilience to a range of stressors. Many of the identified approaches also need to be considered as complementary strategies where the level of management intensity will have to increase over time (Garnett et al. 2012D).

Policy objectives that seek to restore environments to pre-European states or similar aspirational benchmarks will need to be reconsidered, as their value in a changing climate will become increasingly obsolete. Broader spatial and temporal perspectives about conservation benchmarks will need to be employed. To facilitate regeneration, protection of some species at specific locales may have to be abandoned to avoid further exposure and vulnerability in the longer term or to the system as a whole (Garnett et al. 2012D).

The goal of adaptation also needs to be much more explicit and consider limits posed by climate change. Re-thinking of current objectives for natural resource management may be required, as many of those currently set will be both expensive and unsuccessful. Existing goals, targets and thresholds of these management actions need to be reconsidered in order to accommodate climate change threats. While there is scope for improvement and targeted adaptation actions, a major re-think of legislative objectives is required to ensure that actions are sustainable and not maladaptive in other habitats and/or detrimental to existing economic and social values within a given area (Hadwen et al. 2011).

To provide holistic resilience in natural systems, a change in focus from maintaining all species in their current locations to preserving ecosystem service delivery through a range of diverse and robust ecosystems is suggested (Steffen et al. 2009, in Newton 2009). Garnett et al. (2012D) also support an emphasis on ecosystem processes and function in which individual species are indicators rather than the endpoint of conservation. Maintaining areas that will be crucial for species persistence, such as habitats and refugia, needs to be considered from a variety of approaches – not just climate change. Improving connectivity between these areas may not serve all species (Garnett et al. 2012D).

Frameworks for decision-making in the face of both uncertainty and value-based judgements need to be developed, tested and monitored over time. Currently prioritisation of activities is based more on financial efficiency (Garnett et al. 2012D).

***Adaptation needs to take an ecosystem-based approach where resources are considered and directed towards a suite of actions; however, this approach is constrained by institutional complexity.*** Adaptation pathways for the natural environment identified in Newton (2009) include:

- maintenance of well-functioning ecosystems (terrestrial, aquatic and marine)
- protection of a representative array of ecosystems (underpinned by a National Reserve System)
- removal or minimisation of existing stressors
- building appropriate landscape and seascape connectivity
- identification and protection of refugia
- effective monitoring networks
- flexible policy and management approaches.

This combination of actions will help form the basis of an ecosystem-based approach to adaptation. These options have often been implemented in parallel but have yet to be carried out as an integrated climate adaptation package. Integration involves the systematic consideration of the benefits, effectiveness, potential maladaptation, implementation constraints and failure risks of the actions as a whole rather than individually (Lukasiewicz et al. 2013D). Institutional complexity (i.e. rules and funding relationships between and within levels of government) can constrain ecosystem approaches. Increasing the scale and speed of measure implementation is needed in addition to an integrated approach (Lukasiewicz et al. 2013D).

***Taking an ecosystem-based approach to adaptation for natural resource management requires adaptive management, meaning actively experimenting with actions and learning from past activities.*** As some experiments may fail, community expectation must allow for learning through implementation, change of practices, and understanding of undesirable results. Ongoing monitoring is also needed to measure the effectiveness of actions Lukasiewicz et al. 2013D).

***Due to competing demands and pressures on environmental assets, adaptation needs to ensure diverse stakeholder engagement and collaboration to allow value-based decision-making.*** Morrison and Pickering (2011) recommended that government "formally identify, promote and fund collaborative stakeholder partnerships" (p. 6). Their study identified conservation managers and the tourism industry as key stakeholders with potential for collaboration but who were likely to have conflicting adaptation agendas and approaches. Identifying opportunities of mutual benefit (e.g. removal of invasive species) can help build trust and encourage networks for further collaboration.

However, when landowner participation is needed, Lukasiewicz et al. (2013D) also identified numerous constraints that need to be overcome for effective engagement when undertaking climate change adaptation strategies for catchment management areas. These include:

- physical constraints in the form of both natural and infrastructure features, particularly where dams restrict freshwater habitat connectivity
- financial constraints limiting the ability to establish long-term monitoring programs
- social constraints, such as community attitudes towards overbank flows possibly flooding private land
- lack of community concern or aversion to government interventions
- institutional constraints arising from inadequate knowledge of some management options (or lack of adequate funding to acquire expertise).

***Habitat protection is considered the optimal action for assisting the majority of species adapt to climate change within the budgetary limitations.*** Maggini et al. (2013D) explored a process for allocating resources to promote optimal habitat protection and restoration responses to a changing climate. Habitat protection was identified as the optimal action for assisting the majority of species adapt to climate change within the budgetary limitations and was more spatially dominant as the suggested action for 1.8 million $km^2$ of Australia, as opposed to 3000 $km^2$ where passive or active restoration was considered necessary. Maggini et al. (2013D) suggest the optimal focus areas for the allocation of protection and restoration resources (taking into account the cost of implementation, probability of success and benefits across threatened species) are the woodlands and

rangelands of eastern Australia, Northern Territory, north-west Western Australia, and southern South Australia and Victoria, with the focus of the restoration efforts in south-eastern Australia.

***There are conflicting research conclusions regarding whether water pricing is effective in curbing water demand.*** Poloczanska et al. (2012) suggest that pricing is commonly considered an effective strategy, though they point out that not all research supports this conclusion. Grafton and Kompas (2007) (in Poloczanska et al. 2012) suggested pricing amongst a range of fundamental changes in water policy to stave off critical water shortages in Sydney; however, a study by Hoffmann et al. (2006, in Poloczanska et al. 2012) on water usage in Brisbane from 1998 to 2003 suggests that water demand is independent of price.

### 4.7.2 Agriculture, fisheries and forestry

Key findings related to agriculture, fisheries and forestry:

- Agricultural enterprises respond differently to variations in climate; therefore, diversification (meaning cultivating several different crops and livestock) is the most common and effective strategy for mitigating climate-induced variability in net returns from rain-fed agriculture.
- Water trading can be an effective adaptation tool, but not all users will be able to participate and effectively manage associated uncertainty.
- Adaptation in primary production is primarily driven by private sector responses. Government needs to play a supporting role to ensure the effectiveness of adaptation responses through the provision of information and other resources.
- Clear management goals for adaptation under climate change are needed for forest management.

***Agricultural enterprises respond differently to variations in climate; therefore, diversification (meaning cultivating several different crops and livestock) is the most common and effective strategy for mitigating climate-induced variability in net returns from rain-fed agriculture***. However, the greatest benefit for this approach is in moderate rainfall areas where trade-offs between the reduced expected net returns and the benefit of reduced variability can be maximised. There is the least benefit in dry regions, as diversification introduces water-intensive and rainfall-sensitive crops (Kandulu et al. 2012).

***Water trading can be an effective adaptation tool, but not all users will be able to participate and effectively manage associated uncertainty.*** Water trading can be complex and fraught with limitations. It appears to succeed in meeting its intent to reallocate water resources to high value users (e.g. mining, manufacturing, electricity production) at the expense of users such as agriculture, the supply of drinking water and the provision of water to protected ecosystems (Kiem and Austin 2012). In particular, Kiem et al. (2010a) report that water trading and allocations have been challenging for farmers in Mildura. The rapidity and volatility of the market have resulted in the loss of considerable amounts of money for some farmers and some have exited farming entirely.

However, water trading also helped other businesses manage the impacts of the most recent drought, faring much better than they would have otherwise (Kiem et al. 2010b). Loch et al. (2012D) suggest that, on the whole, water markets have been of net benefit for Australian irrigators and will be of increasing importance to adaptation to climate change. Concerns about social implications are discussed by Loch et al. (2012D), and the possibility of transformation change (conversion to dryland farming, relocation, farm exit, etc.) for marginal farms are identified, though it is suggested that there is little evidence of negative social impacts, and that some impacts suggested as relating to water trading are a continuation of ongoing structural change of rural communities that predate water markets.

Key to avoiding or reducing maladaptive water trading and water reform is the need for more complete baseline information on water availability, water quality and current uses (Newton 2009). However, rainfall and stream flow are highly uncertain due to the variability of the climate; this means that defining a sustainable water allocation is extremely difficult (Kiem and Austin 2012). To address this limitation, more research is needed to differentiate which part of the changes in water use (or limitations of water policy) are due to inadequate policy and which parts are due to variable hydro climatic conditions (Kiem and Verdon-Kidd 2011, in Kiem and Austin 2012). Sherval and Askew (2012) note that stakeholders in their study expressed a need for a stable and secure water allocation and buy-back system that is planned and negotiated with farmers.

Loch et al. (2012D) also identified a number of behavioural barriers related to water trading, including unwillingness by some farmers to commit to change given climate uncertainty and variability; the lack of adequate market mechanisms and signals to deal with climate change; economic barriers, including debt levels and access to finance; disincentives for preparedness, including exceptional circumstances support programs; and scepticism.

Finally, Loch et al. (2012D) state that water policies should be designed to address both incremental adaptation decisions (a relatively common decision) and transformative decisions (a rarer decision as it results in a major change in location and livelihood identity). Furthermore, it was suggested that water policy:

- be focused on adaptive change for farmers as they adjust to new levels of water scarcity and land management needs. In particular, policy should help educate irrigators on how planning for water shortages can improve farm viability and profitability
- recognise that change is not possible for all farmers; some parts of irrigated districts perhaps should no longer be supported in the future due to soil conditions, costs, environmental conditions or other factors.

***Adaptation in primary production is primarily driven by private sector responses but Government needs to play a supporting role to ensure the effectiveness of adaptation responses through the provision of information and other resources.*** The Victorian Department of Primary Industries has recognised that farmers' adaptation responses can also have flow-on effects and negative consequences. It has developed a Policy Choice Framework (PCF) to examine the nature of the flow-on effects, suggest policy responses to assist (such as education, regulation, research and incentives), and also consider farmers' likely responses to potential policy interventions. The framework can be used to examine when government investment may be required and whether industry needs could be more effectively met by private service providers or by government agencies (Tostovrsnik et al. 2011).

***Clear management goals for adaptation under climate change are needed for forest management.*** The adaptive capacity of forest management in Australia is supported by several systems, including a well-developed economy, extensive scientific knowledge and technical capabilities, sustainable forest management practices; disaster mitigation strategies and plans, existing policies, and well-developed biosecurity procedures (Boulter 2012). However, previously established principles (such as the principle of setting the composition and biogeography of forests to pre-European settlement conditions as the benchmark) may no longer be appropriate under climate change. Under climate change, it is highly likely that rates of growth and species compositions will change; forests are also likely to shift or change the areas in which they occupy. These impacts will be compounded by other stressors, such as invasive species, disease, habitat fragmentation and economic conditions (Boulter 2012).

Significant financial investment is needed for the adoption of some forest adaptation measures (Boulter 2012). For example, shifting plantation production locations as an adaptation measure for plantations would require significant investment in new infrastructure.

### 4.7.3 Infrastructure, communities and land use planning

Key findings related to infrastructure, communities and land use planning:

- The role of land use planning in adaptation is extremely important but can be contentious.
- There are issues of continued expansion of populations into at-risk areas.
- Regulatory instruments in land use planning need to have greater flexibility to support adaptation.
- A precautionary approach to land use planning is recommended to address risks.
- Making adaptation-related home and property changes can be hindered by a number of factors post–disaster events.

*Key findings for Indigenous communities are also discussed in this section, under their own sub-heading (sub-section 4.7.3.1).*

***The role of land use planning in adaptation is extremely important but can be contentious.*** Owing to its role in guiding economic, social and environmental activities, spatial planning is viewed by many as an indispensable tool for facilitating efficient and equitable adaptation to climate change. However, the use of land

use planning systems to address adaptation issues can be particularly contentious due to uncertainty, the politicisation of the issue of climate change and other factors, raising three particularly prickly issues:

- whether governments should second-guess individual choices and intervene to stop people from putting themselves in harm's way
- the role of government in compensating or assisting individuals who are adversely affected if climate risks materialise (i.e. to share risks and losses)
- to what extent governments should respect the 'property rights' of landholders in designing and implementing land use policies (Macintosh et al. 2013D).

Regardless of these issues, the location and configuration of settlements and infrastructure can influence the vulnerability and resilience of communities to climatic events. By shaping the nature and location of land use and development, spatial adaptation planning can help reduce the adverse impacts of climate change. Urban growth management should consider land for potential abandonment and resettlement as well as plan for more compact communities in areas of reduced risk of inundation, erosion and bushfire (Norman et al. 2012D). Planning processes can also be used as a medium for the dissemination of information about potential climate change impacts, thereby promoting private adaptation initiatives (Macintosh et al. 2013D).

The Queensland Reconstruction Authority (2013) has developed a series of resilience and rebuilding guidelines, covering:

- rebuilding in storm-prone areas
- wind-resistant housing
- planning for stronger, more resilient electrical infrastructure
- planning for stronger, more resilient flood plains.

***There are issues of continued expansion of populations into at-risk areas.*** In many coastal and riverine areas, existing development has expanded and populations have increased without taking into consideration climate change impacts. Planned retreat or relocation is a confronting option to communities, individuals and governments and is only likely to be considered when all other options are exhausted (Hadwen et al. 2011; Hurlimann and Dolnicar 2011).

Over the past two decades, a planning setback policy in Byron Shire has helped serve as a 'managed relocation strategy' in response to historical storm surges. Despite this policy, the ethical, moral, legal, and management issues of relocating beachfront residents have not been addressed. In the absence of more recent extreme storm surges, the policy is also becoming increasingly difficult to maintain as both Council and residents forget the reasons for its genesis (Helman et al. 2010).

In the years since Cyclone Tracy, an increased number of people have moved into the well-characterised storm surge zone of Darwin, and more assets have been constructed in these areas (Haynes et al. 2011). There has also been high population growth within the Indigenous populations in the northern coastal and floodplain regions of the NT. This has increased the exposure of a group already disproportionally vulnerable to climate risks (due to close connections to the land, lack of elementary infrastructure, lower socio-economic status and existing chronic health problems) (Green 2006). Relocation of the northern suburbs of Darwin out of the storm surge area (towards the southern parts of the city) was proposed during rebuilding efforts after Cyclone Tracy; however, this was met with enough public opposition that the suburbs were rebuilt on the original site, thereby continuing to expose residents to a perceived significant future threat (Haynes et al. 2011).

***Regulatory instruments in land use planning need to have greater flexibility to support adaptation.*** More flexible regulatory instruments at the level of state planning policy and in some local planning schemes need to be considered. Macintosh et al. (2013D) suggest that these instruments should include explicit provision for the use of time-limited and contingent approvals in the context of new development. Norman et al. (2012D) suggest that, at least when assisting coastal communities with adaptation, a risk management approach should be adopted that includes progressive learning from experience in order to ensure strategic and statutory planning controls can adapt to a changing environment.

The key advantage of using contingent and time-limited approvals is that they allow current use and enjoyment of land until such time as the hazard materialises (Macintosh et al. 2013D). They are most appropriate in areas where the hazards are likely to develop incrementally over an extended period of time and the changes are likely to be largely irreversible. As such, they are more applicable to coastal areas, which are prone to erosion and permanent inundation, than a bushfire planning context. There is, however, considerable concern among decision-makers that it will be difficult for future governments to exercise options to require houses and other

buildings to be removed without facing claims for compensation or demands for coastal protection measures. There is also concern among utility providers that contingent development approval will make planning and provision of reticulated services (particularly sewerage) very difficult (Macintosh et al. 2013D).

***A precautionary approach to land use planning is recommended to address risks.*** The use of highly detailed flood modelling and mapping, consistent application of overlays and controls throughout Victoria, and a more prescriptive response or precautionary approach to planning are all lessons from robust flood regulations recommended to address bushfires. Related to a precautionary planning approach, Buxton et al. (2011) also highlighted the need to look to the decision by the Victorian Civil and Administrative Tribunal (VCAT) regarding Gippsland Coastal Board v. South Gippsland Shire Council, which emphasised the "need to invoke the precautionary principle and introduced the option for responsible authorities to require coastal vulnerability assessments when considering planning applications. The analysis of risk in this judgement applies also to other risks associated with climate change, including from bushfires" (p. 11). Furthermore, Norman et al. (2012D) support the use of an adaptive decision-making process that incorporates the precautionary principle to ensure the risks of locating future development in the context of climate change is understood.

***Making adaptation-related home and property changes can be hindered by a number of factors post–disaster events.*** After a flood, residents are likely to make and do make changes to their home and property, including improving their garden drainage or building a permanent barrier. Land use or development controls, however, can restrict or delay changes. For example, permits are required in some areas to build a flood levee and restrictions apply. Furthermore, constructing a flood levee is expensive, and perhaps not worth the investment if residents do not think another similar event will occur during their lifetime (Bird et al. 2011). Other residents can be restricted by the structure or material of their homes; brick and slab-on-ground constructions are unable to be modified to reduce future risk. This type of construction should be eliminated if development on floodplains continues (Bird et al. 2011).

#### 4.7.3.1 Indigenous communities

Climate change will have tangible and spiritual impacts on Australia's Indigenous people and their culture as a result of underlying vulnerability, the potential damage to cultural sites and the disappearance of spiritually important species of plants and animals (Griggs et al. 2013D). For example, the study by Nursey-Bray et al. (2013D) of the Arabana people of South Australia demonstrates that the Arabana consider climate change to be a risk and are particularly concerned about availability, access and quality of water, especially in relation to their culturally significant mound springs. They are also concerned about the destruction and erosion of cultural sites due to wind and flooding. In addition, Choy et al. (2013D) describe how opportunities for wild harvesting by traditional owners will decrease as a result of climate change.

The following findings are based on draft NCCARF-funded research. It is also important to note that the research utilised for this section was received after the draft synthesis reports were issued for peer review and state/territory review. Therefore, the findings discussed below should be used with caution, as neither the research utilised nor the synthesis have been independently peer reviewed.

Key findings related to Indigenous communities:

- Climate change adaptation programs targeted to Indigenous communities should focus on empowering communities to identify and implement their own responses.
- Indigenous communities, particularly in remote areas, are often the most vulnerable to climate change. However, remoteness can also increase resilience and adaptive capacity, particularly when a strong connection to country is maintained.
- Climate change adaptation with Indigenous communities requires a holistic, multi-sector, collaborative response.
- Integrating local, Indigenous knowledge with climate change science is critical to adaptation.

***Climate change adaptation programs targeted to Indigenous communities should focus on empowering communities to identify and implement their own responses.*** As only the communities are able to best determine their needs, interests and circumstances, climate change responses need to come from within each community itself; externally imposed or determined solutions are unlikely to be effective or sustainable (Griggs et al. 2013D). As part of research by Petheram et al (2013D) in South Goulburn Island, NT, many participants of workshops and interviews expressed a strong interest in being involved in government decision-making around adaptation. They preferred adaptation options that were community-driven and allowed greater self-sufficiency and independence (Petheram et al 2013D). Bird et al (2013D) likewise note that the concerns of the younger

Indigenous population regarding migration are more in relation to the level of control they will have over movement rather than movement itself.

The desire for control is also described by Memmot et al (2013D), noting Aboriginal concern for greater collaboration and local control of their living environment regarding housing and infrastructure. Indigenous people in the Upper Georgina River Basin area of Queensland and the Northern Territory have negligible control or representation in either the administration or provision of infrastructure with the exception of Myuma, a civil construction and prevocational training organisation run by and employing Aboriginal people. Greater participation in decision-making and the supply of infrastructure would improve adaptive capacity. This is particularly important and challenging for housing, which must be more climate and culturally responsive (Memmot et al 2013D).

In order to identify adaptation options, communities need support in the form of:

- culturally relevant climate change information and research, as well as development of the necessary skills to understand how climate change may affect them and how to determine the most appropriate adaptation options
- meaningful access to regional and national policy and decision-making processes affecting their lands, as well as assistance implementing their selected adaptation options within their community. In particular, governments need to move away from top-down prescriptive approaches to shared decision-making and joint management
- assistance developing opportunities to share knowledge between Australia's Indigenous communities and First Nations people in other countries (Griggs et al. 2013D).

Related to the second point above, research by Nursey-Bray et al. (2013D) suggests that the Arabana may wish to explore co-management or power sharing as it offers a conceptual frame within which to build the partnerships (such as with mining and government) in order to help progress their adaptation and other plans, while ensuring sovereignty is not lost. Power sharing will also need to include a shift in understanding what local and cultural knowledge is and how it affects decision-making. This will also require flexible mechanisms that enable cultural perspectives to be negotiated (Nursey-Bray et al. 2013D).

Griggs et al. (2013D) also note that academia can support communities with information and research but long-term partnerships between communities and academics are needed, which is challenging due to the current institutional structures of research funding. Establishing long-term relationships and the building of trust are important parts of Indigenous culture. Face-to-face interactions are particularly important (Griggs et al. 2013D). Currently, distrust and bitterness exist between the many Indigenous communities, government, academia and others due to a long history of disrespect, marginalisation, exclusion and betrayal.

***Indigenous communities, particularly in remote areas, are often the most vulnerable to climate change. However, remoteness can also increase resilience and adaptive capacity, particularly when a strong connection to country is maintained.*** Specific Indigenous populations will differ in terms of vulnerability and adaptive capacity for a range of reasons related to their history, their environment and exposure to hazards, relationships with stakeholders, their understanding and expectations of climate change (Bird et al 2013D). Many of the Indigenous communities of Australia, such as the Aboriginal communities in Broome, WA; Maningrida and Ngukurr, NT; and Wujal Wujal, Qld, are highly vulnerable to shocks and stresses and are located in hazard-prone places (Bird et al 2013D). Furthermore, factors such as the centralisation of services for remote areas, loss of culture and connection to country, dependence on government funding, lack of monitoring, ad hoc development and land use planning and the multi-faceted issue of poverty are also found to contribute to vulnerability (Bird et al 2013D). Members of Indigenous communities who are in lower socio-economic brackets are more vulnerable to climate change compared to the general Australian population (Choy et al 2013D). Nursey-Bray et al (2013D) note that the Arabana people demonstrate adaptive capacity to respond to climate change and have demonstrated this ability to remain culturally strong in the face of change for millennia. However, "livelihood security, welfare dependency and the disadvantages of race in contemporary Australia remains a point of vulnerability for a significant number of Arabana" (Nursey-Bray et al. 2013D p. 63).

While Indigenous communities are typically considered the most vulnerable to climate change, they are also less likely to re-locate/migrate as the climate changes (Memmot et al 2013D). This underscores the importance of appropriate planning and preparedness at the local community level to best build adaptive capacity in remote locations (Memmot et al 2013D). In these locations, self-reliance will be critical to reduce vulnerability. For extreme weather events, specific and unique evacuation protocols will need to be considered (Bird et al 2013D). At the same time, remoteness can also increase resilience and adaptive capacity, largely due to the strong connection to country in remote areas with limited human distractions and development, giving a close

connection to land and family (Bird et al 2013D). It is also important to note that moving away was not seen as an option for the older generations, whereas younger community members, who may not have as strong a connection to country, view migration as an adaptive response (Bird et al 2013D).

***Climate change adaptation with Indigenous communities requires a holistic, multi-sector, collaborative response.*** Climate change risks and manifestations are salient to the Indigenous population, but more immediate life and livelihood concerns are more specific, salient and articulated (Memmott et al. 2013D). Nursey-Bray et al. (2013D, citing AIPP 2011, pp. 7–8) describe how Indigenous people see links between climate change and other equally pressing impacts or change agents:

> [M]any Indigenous peoples … do not dichotomize between the effects of onslaughts of climate change and the onslaughts of human development. A storm upsurge has as much the same effect as large-scale open pit mining: massive soil erosions and community displacement. A drought has as much the same effect as large-scale logging: destruction of forests, drying of rivers and loss of source of food, among others. Indigenous people's adaptations to these forces have the same objectives – to effectively defend life.

As a result, management approaches need to take into account multiple dimensions and how to manage them beyond climate change adaptation. Adaptation responses can and should occur in parallel with other initiatives to best address long-standing socio-economic and capacity issues (Choy et al. 2013D).

Collaboration and cross-sectoral linkages will also be required. Nursey-Bray et al. (2013D) state that the Arabana people will need to engage and perhaps collaborate with the mining and pastoral communities in order to build collective strategies for managing issues and resources, such as water availability and access. Bird et al. (2013D) note that greater importance needs to be given to linking land use planning, emergency management and disaster management strategies to ensure knowledge is shared. However, the issue of governance and working with differing systems is also important to consider in order to support collaboration and to avoid conflict; governance systems for adaptation planning can be both formal and informal, as well as occur across state, local government and sectoral scales (Brooks et al. 2005 and Richards et al. 2006, in Nursey-Bray et al. 2013D).

***Integrating local, Indigenous knowledge with climate change science is critical to adaptation.*** This includes the recording of Indigenous knowledge, as well as the education and training of environmental managers who can combine Indigenous knowledge with science and actively engage in environmental management (Memmot et al 2013D). Indigenous knowledge and tools, such as seasonal calendars, can also aid in tracking climate change impacts on the environment beyond records established during European settlement (Choy et al 2013D).

The integration of Indigenous knowledge with science will ensure that adaptation plans are understandable by all readers and users:

> Knowledge is not an accepted 'truth' but is in fact constituted differently in different cultural contexts. Western knowledge systems tend to be linear, sequential, and follow scientific principles, whereas Indigenous people's knowledge systems are more circular and different knowledge systems operate concurrently and feedback within a community in various ways (Sillitoe et al. 2002, Croal and Darou 2002, in Nursey-Bray et al. 2013D p. 119).

### 4.7.4 Health and wellbeing

Key findings related to health and wellbeing:

- There is need for a consistent heatwave policy for the management of aged care facilities.
- State government should ensure adequate health services are available, both during and for the longer term after disaster events.

***There is need for a consistent heatwave policy for the management of aged care facilities.*** Each state/territory in Australia varies in its creation of heatwave plans. For example, South Australia has a clearly defined Heatwave Plan administered by SA Health and SAFECOM, whereas Queensland has incorporated the state heatwave plan into the State Emergency Plan. Black et al. (2013D) suggest that, where applicable, a consistent heatwave policy for the management of aged care facilities is needed in addition to the broad State-wide Emergency Management Plan. This policy should be created in collaboration with aged care service providers, the Department of Health and Ageing (DoHA) and the Aged Care Association of Australia. Continuous monitoring and response to extreme heat should also be a component of a regular continuous improvement strategy, and disaster/emergency planning (including heatwave response) should be part of Aged Care Facility Accreditation Standards (Black et al. 2013D).

***State government should ensure adequate health services are available, both during and for the longer term after disaster events.*** Boon et al. (2012D) recommend that state government agencies and NGOs provide counselling and health support services for up to five years after a disaster. As a result of the 2010/11 flood events in Victoria, many residents discussed fears of another flood and being forced to re-live the experience (Bird et al. 2011). Those residents whose wellbeing suffered after the flood felt that they were less able to make changes to reduce their flood risk than others in the community (Bird et al. 2011). In Queensland, residents in Rocklea and Chelmer also reported "not being the same" after the floods, as well as fear of another flood in the near future; multiple suicides in the area were attributed to the floods (Bird et al. 2011 p. 37). Ongoing support to rebuild mental and physical health will increase individual resilience and capacity and contribute to greater community resilience.

*[Note: Health and wellbeing is also closely tied to and important for increasing resilience and adaptive capacity. Therefore, there are also multiple health and wellbeing-related findings within Section 4.1.]*

#### 4.7.5 Business and industry

Key findings related to business and industry:

- Adaptation action within small and medium businesses may be resource constrained.
- Adaptation will likely require the promotion of flexibility and spare capacity in systems – an approach often in contrast with business efficiency.

***Adaptation action within small and medium businesses may be resource constrained.*** West and Brereton (2013D) have developed a consolidated framework to enable boards and executive managers of the Australian business community to develop an approach to climate change adaptation governance, climate change risk assessment and financial disclosure that leads to increased reporting and disclosure without the need for additional and explicit regulations. However, it is noted that this framework is designed to assist mainly large companies; small and medium businesses do not have the resources to implement this framework. Therefore, more needs to be done to assist this sector undertake climate change adaptation assessment activities.

***Adaptation will likely require the promotion of flexibility and spare capacity in systems – an approach often in contrast with business efficiency.*** For seaports, impacts from extreme events has been greatest regarding supply chain issues (e.g. flooding affecting coal supply through the flooding of mines and damaging railway lines) (McEvoy and Mullett 2013). Therefore, adaptation needs to look beyond immediate business environs, as well as consider non-climate drivers. This will require the promotion of flexibility and spare capacity in systems. Port authorities will also need to undertake assessments in collaboration with logistics providers and local/state/national governments in order to ensure supply chain routes and a long-term approach to land use planning for ports are taken into account (McEvoy and Mullett 2013).

## 4.8 Potential policy options and practical adaptation actions

The following potential policy options and practical adaptation responses have been suggested from the research. Note that this is not an exhaustive list of actions; there are many additional actions that also could be pursued. As noted below, a number of the actions are also underway or supported by current Queensland Government activities.

#### 4.8.1 Natural environment and agriculture, fisheries and forestry

##### 4.8.1.1 Coasts

- Establish buffers and rolling easements around coastal reserves and wetlands to allow migration and displacement of habitats (Norman et al. 2012D; Hadwen et al. 2011).
- Establish water trading mechanisms to manage water between tidal estuaries and upstream habitats (Hadwen et al. 2011).
- Develop coastal adaptation plans that identify where the existing coastal buffer is of sufficient width to accommodate future impacts, where immediate protection or retreat is required, and how adaptation actions can be undertaken (Helman et al. 2010).

##### 4.8.1.2 Land and water management

- Develop model flood planning controls for local government (Wenger et al. 2012D). In Queensland, a project, Interactive Floodcheck Map, was undertaken to improve floodplain mapping, leading to a majority of

flood-prone towns being mapped (Queensland Reconstruction Authority n.d.). This mapping is still being undertaken for parts of the state, and the outputs will be valuable in risk assessment and planning for future flood events.

- Remove “raising existing building” and “repairing existing building” from exclusion in proposed changes to the flood provisions in the Queensland Development Code (Mason et al. 2012D).
- Utilise stormwater harvesting to reduce flood risk during extreme events and complement water supply for open space and street trees while also reducing urban heat island effects (SGS Economics and Planning 2010). Some local councils in Queensland are currently utilising stormwater harvesting for this purpose; for example, Brisbane City Council is constructing water storage basins and tanks to collect and treat stormwater for recreational parks and to replace potable water used for irrigation.
- Clarify the responsibilities and regulatory powers of responsible parties for the establishment, maintenance and enhancement and planning controls on developments adjacent to and on stormwater systems. (Verdon-Kidd et al. 2010).
- Develop an integrative climate change model to incorporate terrestrial, marine and sea level models that can consider interactions to allow greater understanding and improved projections for coastal zones (Hadwen et al. 2011).
- Reconsider land use to maintain connectivity at landscape, ecological and evolutionary scales to allow species the opportunity for autonomous adaptation (Hadwen et al. 2011).
- Remove trade restrictions to allow for more efficient transfers of water allocations inter-regionally to facilitate more fluid farm adjustment to water scarcity or climate change; develop better groundwater regulation to avoid over-allocation of the resource; expand water trade products (and cross-sector interaction); improve assessment and approvals procedures to better provide readily available information on processing; remove assessment factors; address handling process complaints, and other critical requirements to reduce water trade transaction costs; and provide greater transparency where potential conflicts of interest may arise (Loch et al. 2012D).
- Develop more robust and detailed market price information signals for water; improve seasonal water allocation announcements through substantial up-front and periodic review to make allocation determinations more transparent; and improve knowledge of potential adaptive responses and their effectiveness across different industries and regions (Loch et al. 2012D).

### 4.8.2 Infrastructure, communities and land use planning

- Require major infrastructure owners to conduct climate risk assessments (McEvoy and Mullett 2013).
- Localise building design requirements beyond current regional zoning in the Building Code of Australia (Hadwen et al. 2011).
- Create building retrofit codes for existing buildings in high risk (flood, bushfire, cyclone) areas. Continue to evolve the draft Flood Standard in the Building Code of Australia (BCA) into a technical standard for commercial and industrial buildings (currently limited to housing). This should also include performance requirements for construction in areas prone to coastal inundation (Mason et al. 2012D). In Queensland, the state government has created a number of resilience and rebuilding guidelines to provide advice on rebuilding, repairing and maintaining homes to reduce vulnerability to a number of climatic risks, including storm tides and cyclonic winds. The government has also created a guide to inform residents and businesses about the key considerations for electricity distribution during floods and cyclones. Most recently, the government announced an allocation of $40 million of the 2013–14 State budget to rebuilding and improving infrastructure after recent extreme events (Queensland Government 2013b).
- Create clear and nationally consistent guidance on public and private obligations in responding to and preparing for climate change, both in terms of managing changes with existing developments and new developments (Helman et al. 2010).
- Undertake property buybacks, compulsory land acquisition and land swapping in high risk areas (Hadwen et al. 2011). However, property buybacks need to be complete and not piecemeal if they are to provide an effective adaptation strategy to hazards such as flooding and bushfire (Helman et al. 2010). In Queensland, councils are encouraged to consider implementing a property buyback program in areas vulnerable to regular flooding; some funding from the Natural Disaster Resilience Program may be available for this purpose (Queensland Floods Commission of Inquiry 2012). However, the state government does not currently operate a state administered buyback program.

- Increase flexibility in legislative and planning frameworks to accommodate future change (Hadwen et al. 2011). Adaptation actions taken today may not be the best solution 50 years from now; therefore flexible responses into the future need to be considered in current decision-making processes and frameworks.
- Consider adaptive responses to climate change in tenancy and property management strategies, including assigning responsibility for adaptation planning and resourcing (Horne et al. 2013D).
- Enable and promote adaptive climate practices in future public housing design guidelines (Horne et al. 2013D).
- Create consistent methodologies and data frameworks to enable information sharing between and within government agencies; this is particularly important for remote communities in the tropical north (Bird et al. 2013D).
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#### 4.8.2.1 Emergency management

- Consider a policy that subsidises insurance purchase for lower socio-economic groups as an alternative to charity donations by government (Boon et al. 2012D).
- Reconsider conventional and standard levels of risk. Although the 1 per cent annual exceedance probability (AEP) flood extent is almost universal across the world as defining an area that needs some level of planning or building intervention, there is no clear reason why this level of risk has been chosen. In many ways, it is out of line with construction practice for other natural hazards in Australia (e.g. ultimate limit design for wind and earthquake is 0.2 per cent of AEP) (Mason et al. 2012D). This issue is currently being considered through a review of SPP 1/03; a joint project of the Queensland Government and the Local Government Association of Queensland has recommended that criteria be developed to determine when a council should be able to adopt a defined flood event less or greater than a 1 per cent AEP flood to regulate residential development (Queensland Floods Commission of Inquiry 2012).
- Establish clear but dynamic thresholds for recognising and responding to a climate event or disaster (Kiem et al. 2010a). The distinction between an event and disaster can be important, as there are often significant changes in strategy and management that follow the declaration of a disaster. This finding primarily refers to climatic events, such as heatwaves, that can slowly establish themselves over a number of days. Other extreme events, such as cyclones, have watch and warning systems established by the Bureau of Meteorology. Events such as heatwaves and droughts are not covered under the existing Natural Disaster Relief and Recovery Arrangements Determination, unlike other events such as bushfires, floods, cyclones, and storm surges.
- Embed researchers within emergency management organisations in order to help emergency management staff better understand climate risks and direct research into needed areas (Howes et al. 2013D).

#### 4.8.2.2 Communities

- Include greater local engagement and involvement in planning adaptation at the community level to identify the most effective strategies for building community resilience and adaptive capacity (Petheram et al. 2010). The Queensland Government's establishment of a Department of Local Government, Community Recovery and Resilience should help the state work effectively with local governments and communities to create and implement effective adaptation and resilience strategies, such as the climate change adaptation strategy being developed by the Department of Environment and Heritage Protection.
- Establish collaborative funding mechanisms to manage risks and encourage agencies to form consortiums across all levels of government and the private and community sectors to work together to solve problems, such as finding ways to increase building resilience to a range of natural disasters (such as floods and bushfires) and climate change (Howes et al. 2013D). In order to have adequate budget for resilience efforts, the Queensland Government is considering, among other strategies, an expansion of the Urban Fire Levy to become an Emergency Management, Fire and Rescue levy to be levied on all properties that receive a rates notice from 1 January 2014 (Queensland Government 2013b).
- Support local community resilience grants with local government to encourage communities to undertake simple projects to increase resilience (Howes et al. 2013D). The Natural Disaster Resilience Program is a competitive grants program funded through shared contributions of the Australian Government, the Queensland Government, and eligible applicants that provide some funding for councils to undertake projects to build community resilience and increase self-reliance (Queensland Floods Commission of Inquiry 2012). The Queensland Government (2013b) is also allocating $40 million of the 2013–14 State budget to

rebuilding and improving infrastructure after recent extreme events; this will be matched by the Commonwealth to ensure the state "can make a start on the many projects local councils want to undertake to improve resilience" (Queensland Government 2013b).

- Establish or enhance formal and informal local support networks (Boon et al. 2012D).

#### 4.8.3 Health and wellbeing

- An education resource on maintaining wellness under extreme heat should be developed for aged care staff and service providers (Black et al. 2013D).
- Specific programs for CALD communities to increase awareness about the health risks of heat exposure and of behaviours to reduce the risk that do not rely on home air-conditioning. Provide information and warnings in multiple languages and through multiple, diverse channels, including religious leaders and school children (Hansen et al. 2012D).

#### 4.8.4 Business and industry

- Explore market-based instruments to encourage homeowners to undertake upgrades to their houses, similar to the Florida Comprehensive Hurricane Damage Mitigation Program/My Safe Florida Home program (King et al. 2012D).

#### 4.8.5 General

- Establish adequate monitoring and review of adaptation policy, including assessment and review frameworks (Robson et al. 2013D; Lukasiewicz et al. 2013D; Aldous et al. 2011; Saintilan et al. 2011).
- Develop a shared information system for sharing risks, uncertainties and other climate-related information for each jurisdiction (Hadwen et al. 2011).
- Develop a standardised approach for evaluating costs and benefits of adaptation investments, particularly for state and local government (Mukheibir et al. 2012).
- Increase clarification and differentiation between local and state government responsibilities, and explore the potential for greater involvement of local government in regional decision-making due to local government's greater connection with local priorities, capacities, barriers and aspirations (Sharma et al. 2013).

### Tools for decision-making

While there are many uncertainties associated with climate change, decisions must continue to be made which need to be robust across a range of possible futures (Dessai et al. 2009, in Mortazavi et al. 2013D). Many research projects have included the development of tools to assist climate change adaptation decision-making through:

- risk identification, including costing
- communication of hazards
- identification, comparison, optimisation and prioritisation of adaptation options
- stakeholder engagement and collaboration (Bennett et al. 2012).

Limitations or challenges associated with tools are formulating objectives, constraints and decisions. Tools, such as optimisation (i.e. a methodology that identifies optimal and robust planning and operational decisions in the face of uncertain knowledge about future climate change), will not produce a single answer, but may help identify a range of 'good' solutions that can form the basis for adaptation (Mortazavi et al. 2013D).

The interpretation of climate projections and integration into adaptation tools remains problematic. A majority of the research reports included recommendations for improved climate change information (particularly for highly localised information), average returns periods and event intensities. However, specific needs and issues were largely not identified. Many of the tools discussed in the research are also specific to or have only been tested within the context of a single sector or at discrete locations. It was beyond the scope of this project to further test these tools. However, most of these tools need broader testing and evaluation beyond the initial development phase to better consider broader applicability. Similarly, consideration also needs to be given to promote tools and how to provide adequate support to the range of stakeholders targeted. This is generally beyond the scope of the initial research funding or beyond the skill set of the researchers in this

project.

***Look for this icon for tool-related reports.*** *This icon identifies research reports where a tool or framework is discussed.*

# 5. Policy and research engagement

The primary purpose of this synthesis was to identify the common emerging adaptation research lessons that can be used by state and territory decision-makers in their efforts to set policy. Viewing the research through this lens also highlighted a number of lessons regarding how the interactions between policy and research may be improved for researchers to better generate knowledge for adaptation policy and for practitioners to better specify what knowledge is needed for action. This section highlights these findings.

**Adaptation policies and strategies need to articulate the adaptation goal in terms of the end point to be attained.** Often adaptation policies and strategies do not directly state the goal of adaptation action in terms of the end point to be achieved. Instead, objectives are vaguely stated with a focus on increasing resilience, reducing risk and maximising opportunities (Hadwen et al. 2011). This creates a number of tensions, including the need to have flexibility in order to manage uncertainty. It also leads to a lack of clear measurable objectives to test through research.

**Participatory approaches can benefit both researchers and policymakers.** A participatory approach to research is important to:

- ensure that existing knowledge and current research is being built upon
- promote access to, and interpretation of data and information necessary for risk assessment and adaptation planning
- allow for iterative feedback to ensure that deliverables are fit for purpose/practical action (McEvoy and Mullett 2013).

A large portion of the research examined for this synthesis studied public engagement and stakeholder collaboration strategies. As supported by the research, engagement with a diverse group of stakeholders is essential and much can be gained through cross-sectoral collaboration. However, the principles and frameworks that emerge from such collaboration can be difficult to incorporate into research reports, as the lessons are best gleaned through the engagement process itself. Furthermore, formal studies evaluating the effectiveness of engagement techniques for climate change initiatives are limited in quality and quantity (Fritze et al. 2009). This is a key barrier to sharing knowledge about successes, failures and possible improvements.

**Improvements could be made to increase the value of research for policymakers.** Often few distinct lessons emerged from the research that would enable decision-makers to take clear actions. More often, the research identified gaps in knowledge, limitations, barriers and research gaps. While this is an extremely important function for research, it is unlikely to be the type of specific information government decision-makers need so they can develop and implement identified adaptation-related priorities. A few researchers noted this issue in their work. For example, Kiem and Austin (2012) state that a fundamental barrier exists between the information that climate science can provide and the information that is practically useful for end users and decision-makers. The source of this disconnect is unclear; it may be “a communication issue, an education issue, a technological issue, or a fundamental philosophical issue (i.e. that scientists think about things differently than practitioners, decision-makers and/or end-users do)” (Kiem and Austin, 2012, p. 22).

Kiem et al. (2010a) also identify a barrier that exists between scientists and researchers providing climate change data and adaptation information, and policymakers, resource managers, emergency response personnel, farmers and others who use the data. This disconnect exists on both sides of the exchange. Information providers do not always understand the needs of end users nor the format that end users need data and information in for it to be useful. At the same time, end users can have unrealistic expectations of what science can currently provide or may not understand the limitations and uncertainties of the data outputs provided (Kiem et al. 2010b). Conflicting time constraints can further increase discord between end users and researchers (Hadwen et al. 2011). As a result of this disconnect, the priorities of policymakers and other end users do not align with the priorities of climate science researchers, constraining both progression of practical climate knowledge and adaptation action (Kiem et al. 2010a).

An example of a strategy that has worked to bridge this gap in the disconnect between researcher and decision-makers is the strong relationship that exists between the City of Melbourne and the Victorian Centre for Climate Change Adaptation Research (Hussey et al. 2013D). This is noted as allowing information providers to gain insights into the decision-making process and what is needed by the organisations, as well as encouraging “a legacy within organisations to identify and assess adaptation options” (p. 68). This relationship is promoted by Hussey et al. (2013D) as something that should be further explored and encouraged within other organisations (government, NGO and private) and research institutions due to the mutual benefits it provides.

**Care needs to be taken in research to avoid stakeholder fatigue and disenfranchisement.** Kiem et al. (2010b, p. 17) report stakeholder fatigue in many rural areas, meaning people are becoming tired and sceptical of climate change research projects because they have been involved in so many but have seen few positive outcomes: "Further efforts are needed to coordinate 'outcome-based' or applied research activities – a practice that not only provides the benefits of interdisciplinary and interagency knowledge, but also respects those we are working with by not overburdening them with separate and disconnected research interventions".

**There is a need for consistent climate change terminology use across research bodies, government departments, relevant industry and organisations to allow greater understanding between research providers and research users.** There are current discrepancies in meaning for some words – including 'adaptation', 'prediction', 'projection' and 'scenario' – in documents relating to climate change and adaptation (Verdon-Kidd 2012; Hadwen et al. 2011). Some of these are due to different sectors or organisations adopting different meanings, others due to misuse through lack of knowledge of accepted meanings. It is noted that there are current lists of terminology widely adopted by researchers, predominantly the IPCC definitions; however, there is a need to adopt and educate on standard definitions (Verdon-Kidd 2012). This lack of consistent terminology use also leads to an increase in misunderstanding between the information providers and information users, as identified by Kiem et al. (2010b).

## 5.1 Strategic cross-sectoral research gaps

A common element of the literature reviewed was identification of research gaps and new questions. Many of these recommendations were focused on areas where further research is required. While it is important that these issues are captured, it is equally important that gaps are identified in relation to application of the research findings themselves for specific end users, in this case state and territory decision-makers.

**Understanding of autonomous adaptation.** Although autonomous climate adaptation has been observed in some systems, it is not known whether or how long this will be able to match the rate of climate change. Similarly, thresholds of ecological, social and economic resilience are unidentified for many systems and communities. For example, there are significant knowledge gaps regarding which species are capable of shifting their habitat range (including pests). Without this knowledge, the role of protected area conservation as an adaptation option is likely to be limited (Hadwen et al. 2011).

**Adaptation effectiveness.** Research to assess the efficacy potential and unintended consequences of different potential adaptation actions is limited. This research needs to be done at a regional scale as it is likely that consequences will vary according to local settings and in response to interactions with each other and regional non-climatic stressors (Hadwen et al. 2011). It is acknowledged that the number of on-ground human climate change adaptation practices remains limited (or optimistically, are difficult to identify due to integration). Measuring the success of adaptation actions needs to be undertaken in the short, medium and long term and will need to be informed by careful monitoring.

**Understanding of the limits of uncertainty.** For effective and robust adaptation-related decisions to be made, realistic and practical, useful information on climate change impacts is needed (Verdon-Kidd 2012). For example, a lack of understanding of climate change impacts has been identified as a major barrier to adaptation interventions for freshwater ecosystems (Robson et al. 2013D). However, it appears that this information is not as critical for interventions to improve community resilience. Uncertainty is also unlikely to be reduced for many sectors in the near future (if at all), so effective decisions will need to be made under uncertain conditions (Verdon-Kidd 2012). Understanding for which sectors the uncertainty of climate change impacts limit adaptation action and for which a reduced uncertainty is largely unnecessary would facilitate implementation. It is also important to understand the causes and structure of uncertainty so that decisions can be reviewed and changed as needed over time (Verdon-Kidd 2012).

**Non-physical and compounding vulnerability.** Research and interest remain focused on adaptation associated with physical vulnerabilities that can be incorporated into policymaking. However, non-physical vulnerabilities, such as social and economic vulnerabilities, and how different factors interact and may compound vulnerability remain poorly understood. This information would be useful to inform approaches such as scenario planning. Examples of where this has been identified in the literature include:

- the interaction between heatwaves, air quality and urban form, establishing a better understanding of sub-groups vulnerable to temperature extremes and characteristics that increase vulnerability (QUT 2010)
- the risks of multi-city extreme events and their effects on emergency services, insurance and disaster relief (QUT 2010)
- mental health and nutrition issues in Indigenous communities where climate change impacts affect ceremonial hunting and food gathering practices (Green 2006).

# 6. Conclusions

## 6.1 Fundamental adaptation challenges

The complexity of climate change adaptation cannot be underestimated. A wide range of issues play a role, including national and state policy contexts, local institutional constraints, short- and long-term climate variability, local community development strategies and local environmental conditions, play a role. As pointed out by Gross et al. (2011) “adaptation to climate change should be considered as one aspect in a complex, ever changing set of environmental, social and economic circumstances.” (p. 77). Through recognition of the emerging fundamental challenges, adaptation approaches can be identified (specific options will be highly contextualised and therefore beyond the scope of this synthesis approach). The breadth of research reviewed – both in terms of location and sector – highlight the complexity of these challenges and common themes, outlined in Table 4. These challenges include potential implications for policy development, programs and management undertaken by state and territory governments.

**Table 4: Summary of the fundamental challenges relevant to state and territory government decision-makers**

| Fundamental challenge | Issue | Policy implications | Example |
|---|---|---|---|
| **Climate change uncertainty** | Assessing the impacts of climate change is uncertain due to inherent uncertainty in climate change and numerical modelling but also because impacts will vary over time and space and will be synergistic.<br><br>Adaptation planning needs to consider the possibility that most uncertainties are unlikely to be resolved by the time decisions need to be made. | Because of uncertainty, it will be difficult to prioritise adaptation planning, and when decisions are made they are likely to be contested.<br><br>Failure to accept uncertainty is resulting in inertia and stifling the development of flexibility.<br><br>Issues of uncertainty should be considered a limiting factor to adaptation. | Use of a range of decision support tools such as scenario planning and sensitivity analysis can help identify adaptation options that are robust under a range of conditions or identify trigger points for new adaptation options. |
| **Working with a changing baseline** | Climate change represents only one of many drivers of change. Taking into account other drivers is essential to help inform long-term adaptation planning. | There is significant economic, institutional, ecological risk in planning adaptation responses without considering all pressures.<br><br>Adaptation needs and effectiveness will change over time in response to diverse factors. By not considering these shifts, investment may be ineffective in the longer term and new risks may arise. | The early introduction of flood barriers has encouraged the concentration of development in high risk floodplains. However, the effectiveness of these barriers has not been reviewed against future increases in rainfall. |

| Fundamental challenge | Issue | Policy Implications | Example |
|---|---|---|---|
| **System approaches** | Climate change is complex, and vulnerability will be driven by ecological, social and economic responses, interactions between sub-systems and interactions across scales.<br><br>To maximise adaptation effectiveness, create opportunities for change and avoid maladaptation; a holistic approach to adaptation needs to be considered. | Mechanisms for collaboration between and within government need to be facilitated. Collaboration with stakeholders will also be essential.<br><br>Processes by which to consider trade-offs and the distribution of costs and benefits at local and regional scales will need to inform decision-making. | Water trading/pricing impacts multiple systems and sectors, including natural resource management, agriculture, industry, infrastructure and community resilience. |
| **Communication and engagement** | There is no value in a 'one size fits all' approach to engaging stakeholders on climate change adaptation. Specific, targeted engagement is required. | Greater consideration of the interests, needs and concerns of specific stakeholders is needed to build community support for adaptation. | Information and warnings need to be provided in multiple languages and through multiple, diverse channels. |
| **Articulation and implementation of adaptation objectives** | Historical policy objectives may no longer be appropriate in the face of climate change and may limit opportunities for transformational change.<br><br>Failure to explicitly state adaptation objectives may create unrealistic community expectations and fail to trigger autonomous adaptation responses by individuals. | Natural resource management, biodiversity conservation and land use planning objectives will be particularly affected.<br><br>By working with stakeholders to articulate adaptation objectives, conflict can also be avoided and barriers addressed.<br><br>This will also help to coordinate the integration of climate adaptation into existing policies, strategies and operational activities at state government departmental and agency portfolio level. | Biodiversity conservation may need to consider adaptation options to maintain ecosystem function rather than the conservation of individual species.<br><br>The establishment of habitat corridors may need to focus on the needs of a different range of species than what might currently be expected. |
| **Limits to adaptation** | Limits to adaptation may be artificially imposed and will vary over time. Limits may be imposed by societal values, physical or resource constraints or institutional constraints. | If limits to adaptation are temporary or artificial constructs, effective stakeholder engagement, flexible policy and clear articulation of short- and long-term adaptation objectives will be critical. | Community acceptance of adaptation options may change in response to conditions – e.g. the use of recycled water as described by Hurlimann and Dolnicar (2011). |

| Fundamental challenge | Issue | Policy Implications | Example |
|---|---|---|---|
| **Monitoring and review of both risks and adaptation responses** | Monitoring is needed to support flexible decision-making over time. Monitoring can also help define triggers for action, including different or intensified adaptation responses.<br><br>There is currently little knowledge or experience in evaluating adaptation options. | Consideration of how climate change can be taken into account when reviewing and updating existing policies | Natural resource management requires adaptive management, meaning actively experimenting with actions and learning from past activities. Monitoring is essential to evaluate actions. |
| **Financing adaptation** | Issues around who pays for adaptation are largely still unresolved.<br><br>Linked to this issue is also the concerns of government in relation to legal liability. | Private sector investment in adaptation will be guided by government responses and support.<br><br>Use of traditional tools such as cost–benefit analysis, is emerging but there is limited knowledge on how to best consider distributional issues. | Investment by the government in coastal protection is proving a direct benefit to individual property owners.<br><br>Government subsidy post-disaster can disincentivise households to cover their own exposure through insurance. |
| **Learning from recent extreme weather events** | Action on the ground to date tends to focus on responses to past severe weather effects. Reviews of these events do not generally consider the implications for the future under a new climate.<br><br>Substantial long-term, continuous changes may require different responses than limited, temporary events such as floods, bushfires and droughts. | While it is important for government to take a continuous improvement approach following extreme events, current recovery support may be compounding risk and reducing the resilience of communities.<br><br>Opportunities for significant change are lost due to need to support recovery efforts in the short term and as communities discount the impacts of past events. | Consideration of climate change in reviewing extreme events.<br><br>Exceptional Circumstances payments for farmers can work against communities trying to adapt and transition (Kiem et al. 2010b). |

***Climate change uncertainty***

There are clear challenges associated with the scale of adaptation required, the timing of when to introduce interventions and how interventions are best delivered. Humans tend to be relatively short-term thinkers, and Australia's variable climate and relative short history of European settlement may further discourage consideration of long-term changes in climate. In particular, climate change projections for extreme events have significant levels of uncertainty – both in terms of timing and frequency. The reality that improvements in climate change science can only partially reduce this uncertainty requires that adaptation planning accepts these uncertainties and no longer uses them for justification of inaction. These uncertainties also highlight the need for flexibility, both as new information emerges and as society evolves.

### *Working with a changing baseline*

Climate change uncertainties are not the only constraints, however. Changes within society and the environment – both in response to climate change and other forces and their influence on adaptive capacity and vulnerability – remain one of the greatest limits to effective adaptation. Use of a 'business as usual' baseline to compare impacts and vulnerability over time is overly simplistic at best and misleading at worst. Changes in global and regional economies, demographic shifts and technological advancements will fundamentally shift underlying vulnerability and adaptive capacity. From these, changes in values and priorities will also emerge. Fortunately, government policy is reviewed and updated regularly as new information emerges and communities change. The complexity of changes to consider, however, may require policy and management objectives – particularly in relation to natural resource management, disaster recovery and land use planning – to be reconsidered at a fundamental level. Objectives must be considered from a non-stationary baseline and in light of longer-term risks, multiple scales and in the context of potentially diverse values.

### *System approaches*

Climate change is complex, and vulnerability will be driven by ecological, social and economic responses, interactions between sub-systems and interactions across scales. The range of areas potentially impacted will also require an unprecedented level of collaboration and agreement between government departments, different levels of government and other organisations. This can be a considerable challenge, particularly when responsibilities are not clearly defined or when agendas conflict.

### *Communication and engagement*

While government engages with community stakeholders on a frequent basis, engagement around climate change can be particularly challenging. Some members of the community are unwilling to link climate change to observed phenomena. At the opposite end of the spectrum, there are portions of communities overwhelmed by the picture of unstoppable and pervasive climate change. As such, communication regarding disaster preparedness and climate change often need to be separate and offer bespoke, tailored messaging depending on a community's worldview, interests and needs. In fact, a significant proportion of the research reviewed for this synthesis recommends the need to better consider messaging and communication on climate change adaptation.

It is crucial to engage both stakeholders and the broader community to get behind adaptation actions. Engagement can help increase community preparedness, create ownership of and buy-in for adaptation options, and improve social cohesion. By engaging the community, local and historical knowledge can be also be accessed to help identify risks, opportunities and maladaptive options. In the Northern Territory and South Australia, for example, the engagement of Indigenous communities is considered beneficial for a range of adaptation activities, including emergency management and natural resource management (Bardsley and Wiseman 2012; Hadwen et al. 2011; Haynes et al. 2011).

### *Articulation and implementation of adaptation objectives*

Clearly articulating adaptation goals (together with options) is seen as a key to engaging the community. Well-defined objectives can also help coordinate the integration of climate adaptation into existing policies, strategies and operational activities at state government departmental and agency portfolio level. While the articulation of objectives seems relatively easy, actually ensuring action is often more difficult.

Underlying this challenge, and many of the challenges discussed so far, is political will. Clearly articulated objectives can be watered down due to political sensitivity or can be hard to implement. Other change drivers can take political precedence over climate drivers, crowding out adaptation considerations. It also can be hard to enact long-term plans within a short-term political environment. Overcoming this barrier with political leadership will be essential for adaptation success.

### *Monitoring and review of both risks and adaptation responses*

Monitoring of both risks and adaptation responses is needed to support flexible decision-making over time. Monitoring can also provide evidence of how natural and human systems are changing as a result of climate change, as well as provide support for the continuous implementation of effective policy interventions. Unfortunately, there is currently little knowledge or experience in evaluating adaptation options. There also can be a lack of understanding of what needs to monitored or a lack of feeling of urgency to establish appropriate systems. Even when it is known what to monitor, monitoring can be difficult to implement as it frequently requires a long-term commitment of time and continuity of funding. This is likely one major avenue for increased collaboration between researchers and government.

***Financing adaptation***

Issues around who pays for adaptation are largely still unresolved. This is perhaps the greatest challenge for state government policymakers, as it can be unclear how much the private sector will engage and take action. Related to the other actions discussed, institutional barriers, political will and uncertainty can reduce the willingness of government to dedicate limited financial resources to a problem, particularly when responsibility is unclear. This suggests that identifying roles and responsibilities is the first step towards addressing this challenge.

***Learning from recent extreme weather events***

Responses to recent extreme events have been examined to identify potential adaptation lessons, particularly with regards to floods, bushfires and droughts. Unfortunately, the findings for long-term adaptation are not as clear. While it is critical that we learn from and address the many issues that arise from these events, we may still be missing key adaptation lessons. Of the formal reviews of these events studied by different pieces of research, the potential influence of further climate change was not considered to gauge or identify where responses beyond 'business as usual' may be necessary or to test recommendations made. Further opportunities are lost by the rush to restore communities and meet shorter-term needs.

Using these experiences as the basis for adaptation planning may also introduce risks and bias. As noted by Kiem et al. (2010b) strategies to deal with extreme events can be irrelevant under climate change as evidenced by 'exceptional circumstances' payments, which were originally enacted as an emergency response; in reality, they worked against rural communities adapting to drought and drier conditions in the long term.

The question of whether experience with disaster events improves community resilience also remains inconclusively answered – it appears that it depends on a range of factors, unique to each location, each event and each point in time. No research has challenged the validity of the question for policy, which is particularly important when considering the long term nature of climate change.

However, despite the challenges, it is also important to recognise that the experience from extreme events can bring hope. Stories of autonomous self-organisation and neighbourhood support highlight the need to continue efforts which strengthen a sense of community and ultimately improve adaptive capacity. Examples such as the Queensland 'Mud Army' and 'Bake Relief' demonstrate the potential role of social media along with the capacity of the human spirit. Other local or autonomous responses to recent and current climatic stressors have also been identified, including how some farmers have shown innovation and flexibility in adapting livelihood systems to changeable and marginal environments through crop diversity and water management in response to climate variability. Local knowledge provides considerable assets in the form of social capital and natural capital, demonstrating innovation in the face of adversity. Recognition and promotion of these behaviours needs to be considered and targeted in community support programs.

## 6.2 Key lessons for state and territory government decision-makers

While a key focus on the research reviewed has been issues associated with research constraints, gaps and limitations, a number of lessons for decision-makers have been identified.

***Increase effort in identifying adaptation opportunities and promoting positive change.*** While there is a need to continue to prioritise adaptation aimed at reducing the risk of harm and in evaluating the limits and barriers of adaptation, there are benefits in seeking to identify potential opportunities, including incentives and regulation. Careful messaging will be required, but this approach may help to positively engage stakeholders, especially those that may feel overwhelmed by climate change. Clear opportunities already exist. For example, on average 35,000 new buildings are built each year in Australia, offering numerous opportunities to improve the climate resilience of Australia's future built environment.

***Monitor and evaluate existing adaptation practices for ongoing adaptation.*** As well as being necessary to monitor the effectiveness of current adaptation options, including those intended to increase adaptive capacity, an evaluation process is critical for continuous improvement, to build trust with stakeholders, and to effectively implement adaptive management.

***Clearly define specific adaptation objectives***. Understanding what the government's appetite for risk is and what outcomes are expected for an adaptation approach are critical for decision-making, implementation and evaluation. Developing these objectives in consultation with stakeholders will help build support and send appropriate messages to trigger private adaptation. Defining adaptation objectives needs to go beyond 'motherhood statements' (e.g. 'a community that is resilient to climate change') and actually articulate what that

may look like. It is also important to more clearly define roles and responsibilities of who needs to play an active role in carrying through the objectives and associated actions.

***Ensure structures and institutions are flexible and can react to emerging issues and unforeseen events.*** From land use planning to natural resource management to primary production, the research reviewed for this synthesis frequently reiterated the need to ensure governance systems are flexible in order to respond to unforeseen events as well as incremental changes. Flexibility will also allow for continuous learning, which is essential for adaptive management.

***Continue efforts to build community cohesion.*** Building a sense of community is important to increase adaptive capacity and resilience but will have a range of benefits beyond climate change adaptation. Communities with a strong sense of place and greater social networks tend to have greater adaptive capacity than communities without these characteristics. The topic of climate change does not need to be the focus of community building programs in order to be advantageous for adaptation. This will require continued close engagement with local government and community organisations.

***Avoid calm weather planning.*** Taking a risk-based approach that factors in both experience from past extreme events and future potential climate change is a more robust approach for adaptation planning. This approach will also help focus on the co-existence of adaptation needs for diverse events, such as water management planning, which considers both floods and droughts.

***Create opportunities for greater engagement between researchers and end users***. To take advantage of research and to support better adaptation planning, government decision-makers need early and frequent engagement with the research community. There also needs to be a greater focus on end-user–focused research that supports policy development and implementation.

# Appendix A: FORNSAT Interviews

## FORNSAT Interviews – Summary of issues and directions

*Report compiled 6 August 2012*

NCCARF appointed AECOM to prepare a synthesis of adaptation research relevant to each state and territory. The starting research questions for this research are:

- What useful and practical analysis for state and territory policymakers can be provided from the adaptation research now available?
- What are the implications of that analysis for sectors in individual states and territories?

The synthesis reports are to be targeted specifically to the needs of state and territory governments. Therefore, a critical success factor for this project is the extent that the synthesis meets these needs.

To commence this work, AECOM sought input from individual states and territories with regards to:

- the scope and focus of the synthesis
- the inputs into the synthesis
- broader stakeholder engagement
- the outputs of the synthesis.

This input was gathered through interviews with FORNSAT representatives and other invited guests from each state and territory (excluding Tasmania) between 26 July and 6 August. Appendix Table 1 provides a full list of interviewees by state or territory.

### Appendix Table 1: Interviewees by state/territory

| State/territory | Representatives interviewed |
|---|---|
| New South Wales | Christopher Lee |
| Victoria | John Houlihan |
| Western Australia | James Duggie |
| South Australia | Stephanie Ziersch |
| Queensland | Lynn Whitfield, John Locke, Nancy Esler, Craig Walton, Kirsten Lovejoy and Daniel Rodriguez |
| Northern Territory | Bethune Carmichael |
| Australian Capital Territory | Kathy Tracy and Tim Wong |

### Summary of findings

Interviewees were asked the same seven interview questions. Feedback received has been qualitatively summarised by question, highlighting key themes, similarities and differences between responses.

**1. What do you most want out of this synthesis of adaptation research? What would be of greatest value to the State's adaptation program?**

FORNSAT representatives expressed the following needs or interests in this project:

- Identifying and aggregating policy-focused and practical, applicable research relevant to each state and territory
- Providing a clear picture of what research has occurred and where (including types of research). Also, identifying research gaps and research opportunities
- Supporting the strategic positioning of adaptation efforts and investment by demonstrating the need for adaptation research and benefit of action

- Drawing out conclusions that can help decision-makers (ensure the synthesis is pragmatic and demonstrates how research can clearly inform actions)
- Identifying transferable lessons from and comparisons with other regions
- Demonstrating how NCCARF research is complementary to other state-based adaptation research investment.

**2. Has your state defined or articulated its priority climate change risks or adaptation priorities?**

Few states and territories have formally or publicly defined their priority climate change risks or adaptation priorities. However, where risks had been identified in internal documents, there was a willingness to share this information with AECOM on a confidential basis where feasible.

A regional approach to adaptation planning is being used by a number of states. In these cases, states are working with regions to define their priorities.

Some interviewees suggested specific plans or stated policy objectives that should be used to organise findings. It should be noted that tailoring a state or territory synthesis report to a specific plan's actions is likely to be beyond the scope for this project. AECOM will use existing plans and policy objectives to understand government needs and to guide the creation of the project's synthesis framework. A consistent synthesis framework and approach will be used for all states and territories.

**3. Have any literature reviews or broader vulnerability assessments been undertaken that could help inform this project?**

Sector-specific and regional vulnerability assessments and climate change impact assessments have been completed or are underway by most states and territories. Many have also internally identified adaptation research needs or have conducted internal literature reviews. AECOM has asked representatives to share this internal information if feasible and relevant.

**4. Where you have used research to inform policy and program development, what have been some of the key factors that have ensured the research is useful/applicable?**

Many states and territories conduct research for policy and program development in-house or in close partnership with universities. Research undertaken or directly commissioned by individual government agencies is preferred as these agencies are best placed to consider issues pertinent to their sector or department. Similarly, research with active end-user engagement tends to have greater levels of confidence, increased potential for application, and fewer barriers for uptake.

Utilising uncommissioned academic research can be challenging for governments as it tends to be less directly relevant to state or territory needs and/or less practically focused. Some states view this project as an important first pass to identify relevant literature, indicating to states and territories which researchers to engage with further.

The language used in research can also be important for uptake, particularly for less scientific- or academic-focused government staff and policy officers. Language needs to be accessible to a range of users and clearly articulate lessons.

**5. What elements of this project would be most useful for you?**

FORNSAT representatives had differing views of the utility of project elements, particularly related to the length and detail of the reports. Appendix Table 2 displays a qualitative assessment of the level of state and territory interest in project outputs.

**Appendix Table 2: Project outputs and level of interest**

| Project element | Level of state/territory interest |
|---|---|
| A searchable database of NCCARF research | *High*. Considered the most useful project element by one representative. However, representatives frequently requested that the database include more than just NCCARF research. |
| A scan of adaptation research relevant to your state and territory | *High*. Considered useful by all representatives. Some also expressed the importance of including transferable learnings from other locations within Australia. |
| A scan of adaptation research relevant to targeted government priorities or critical sectors | *Low*. Considered the most useful project element by two representatives. However, very few states/territories were able to provide clear direction on their key priority sectors. |
| A stand-alone short report of the synthesis findings (e.g. a document of 6–10 pages for non-technical audiences) | *High*. Considered useful by the majority of representatives; deemed valuable for engaging with ministers and senior management but less valuable for adaptation practitioners. Many representatives stressed the importance of not over-synthesising the research and warned about the potential risks of editorialising. Others stated the need for the synthesis to include analysis and clear direction to end users. |
| A detailed technical report outlining the project methodology and findings | *Medium*. Considered highly useful for representatives who felt the short synthesis would not provide practitioners with enough technical detail. However, multiple representatives had little interest in this report. |

Representatives occasionally suggested additional project elements not listed above. Suggestions included:

- providing useful guidance on how to reach/engage communities (the general public) to build resilience
- creating outreach materials to communicate project progress and share the outputs of this project to a broader audience (communities, stakeholder groups, etc.)
- providing guidance on how to use, maintain and adapt the database.

Representatives also provided input on how best to benchmark research within the database. Suggestions included:

- including a variety of categories and key words to search the database, such as type of methodology used, outputs, geography, knowledge transfer mechanisms, completion date
- considering how the database can mesh information between states.

**6. Who do you see in state/territory government being the key audience?**

Interviewees generally saw two audiences for this work:

- high level decision-makers, where a short, sharp synthesis can help demonstrate the need for adaptation
- policy officers, practitioners, sectoral experts, existing adaptation/climate change working groups, who will want detail that is specifically relevant to them. A searchable database and technical summary is likely to be of greatest interest to this group.

A few states and territories also highlighted the importance of local governments in adaptation planning and emphasised their place as a key audience.

**7. How can the value of this project to other end users in your jurisdiction best be communicated?**

FORNSAT representatives intend to directly engage with existing interdepartmental working groups throughout this project. Where existing working groups do not exist, representatives intend to utilise existing databases of government stakeholders to distribute information. Working groups and stakeholders will be asked to provide any relevant adaptation research, review the list of adaptation research to be synthesised, and attend the workshops in November / December to provide feedback on the draft synthesis. In order to ensure end users are responsive and engaged, some representatives emphasised the need for the synthesis to be linked to each government's policy priorities.

At the end of the project, FORNSAT representatives plan to distribute project end products to a broad audience of government stakeholders using their existing information channels.

Interviewees requested that AECOM provide short, sharp project updates to assist with outreach. It will also be important to consider the timing of communication and outreach (especially in relation to combined run-up to Christmas and potentially bushfire season).

# Appendix B: Nationally relevant NCCARF projects

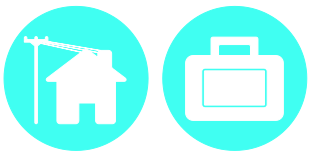
A total of 23 NCCARF research projects included in the synthesis have been determined to be national projects – projects that are not limited to specific locations, have either no geographical case study region or cover common issues for Australia.

**Appendix Table 3: Nationally relevant NCCARF research projects**

| ID | Lead Author | Year | Title | Sectors |
|---|---|---|---|---|
| SI1004 | G. Barnett | 2012 | Pathways to climate adapted and healthy low income housing |  |
| P1FVA5 | S. Boulter | 2012 | A preliminary assessment of the vulnerability of Australian forests to the impacts of climate change synthesis |  |
| SD1117 | R. Crompton | 2012 | Market-based mechanisms for climate change adaptation: Assessing the potential for and limits to insurance and market-based mechanisms for encouraging climate change adaptation |  |
| FW1109 | M. Dunlop | 2013 | Contributing to a sustainable future for Australia's biodiversity under climate change: conservation goals for dynamic management of ecosystems |  |
| S3BCM1 | D. Hine | 2013 | Enhancing climate change communication: strategies for profiling and targeting Australian interpretive communities |  |
| EM1102 | M. Howes | 2012 | The right tool for the job: achieving climate change adaptation outcomes through improved disaster management policies, planning and risk management strategies |  |
| TB1105 | L. Hughes | 2013 | Determining future invasive plant threats under climate change: an interactive decision tool for managers |  |
| SD1109 | K. Hussey | 2013 | An assessment of Australia's existing statutory frameworks, associated institutions, and policy processes: do they support or impede national adaptation planning and practice? |  |
| S3BCM2 | G.S. Johnston | 2013 | Climate change adaptation in the boardroom |  |
| P2LTA6 | A.S. Kiem | 2012 | Limits and barriers to climate change adaptation for small inland communities affected by drought |  |
| EM0901 | M.E. Loughnan | 2012 | A spatial vulnerability analysis of urban populations to extreme heat events in Australian capital cities |  |
| SI11 01 | A. Macintosh | 2013 | Limp, leap or learn?: Developing a legal framework for adaptation planning in Australia |  |
| TB1102 | R. Maggini | 2013 | Optimal habitat protection and restoration for climate adaptation. |  |

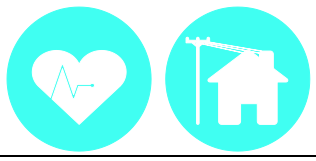
| ID | Lead Author | Year | Title | Sectors |
|---|---|---|---|---|
| SI1106 | K. Mallon | 2013 | Climate change and the welfare sector – risk and adaptation of Australia's vulnerable and marginalised | |
| S3BIB1 | L. Mason | 2012 | Leading practice guidelines: planning and preparing for extreme weather events | |
| S3AFS1 | D. Michael | 2012 | Food security, risk management and climate change | |
| S3ABA1 | P. Mukheibir | 2012 | Cross-scale barriers to climate change adaptation in local government, Australia | |
| P2IMLR | E.S. Poloczanska | 2012 | iClimate Project | |
| S3AUN2 | A. Randall | 2012 | Understanding end-user decisions and the value of climate information under the risks and uncertainties of future climate | |
| EM1101 | J.P. Reser | 2012 | Public risk perceptions, understandings, and responses to climate change and natural disasters in Australia, 2010 and 2011 | |
| P1ACP1 | T.F. Smith | 2010 | The nature and utility of adaptive capacity research | |
| EM1103 | S. Trueck | 2013 | Developing an Excel spread sheet tool for local governments to compare and prioritise investment in climate adaptation | |
| S3AUN1 | D. Verdon-Kidd | 2012 | Bridging the gap between end-user needs and science capability: dealing with uncertainty in future scenarios | |
| SI1005 | C. Woodroffe | 2012 | A model framework for assessing risk and adaptation to climate change on Australian coasts | |

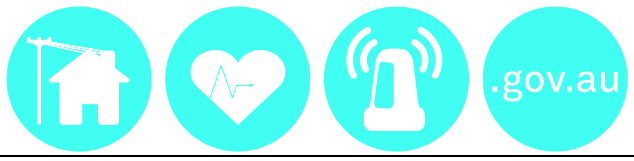
# Appendix C: NCCARF research summary – Queensland

| The 2008 floods in Queensland: a case study of vulnerability, resilience and adaptive capacity | |
|---|---|
| **Authors (Year)** | A. Apan, D.U. Keogh, D. King, M. Thomas, S. Mushtaq, P. Baddiley (2010) |
| **Status** | Final report |
| **Summary** | This report assessed how communities regularly impacted by flooding adapt and respond to the events (including identifying the extent that mitigation and adaptation measures have been implemented), explored the characteristics of 'on-the-edge' communities, and the vulnerability, resilience and adaptive capacity of households and businesses to flooding. Specifically, the towns of Charleville and Mackay were assessed and compared in response to historical floods focusing on the 2008 floods that affected the regions.<br><br>Vulnerable populations identified in the case studies included the elderly (limited facilities for evacuation and accommodation), new migrants (possible lack of social network and language barriers), and rural populations (distance and difficulty accessing information). The difficulty in obtaining adequate insurance in Charleville was identified as a major vulnerability. The project found that resilience was not necessarily linked to economic capacity, with social capital and community connections seen to play a more significant role. This community connection was identified to lead to a sense of belongingness and personal responsibility to do things such as prepare and respond adequately. Adequate planning and development were also identified as crucial for community resilience. |
| **Methodology** | This study undertook a literature review; data was collected; surveys and interviews were conducted. |
| **Output** | Knowledge |
| **States (specific location)** | Queensland (Charleville, Mackay) |
| **Sector Relevance** |  |

| Impact of the 2010/11 floods and the factors that inhibit and enable household adaptation strategies | |
|---|---|
| **Authors (Year)** | D. Bird, D. King, K. Haynes, P. Box, T. Okada, K. Nairn (2011) |
| **Status** | Final report |
| **Summary** | This report assessed factors that impede and assist adaptation strategies in flood-impacted areas. The report focused on what can be learned from case study communities in Queensland and Victoria affected by the 2010/2011 floods.<br><br>Barriers to adaptation that were identified in the report include financial constraints, pre-existing building construction and lack of skills and guidance on response and adaptation. The lack of awareness, preparedness and education for flooding events and the aftermath (as opposed to some other extreme weather events such as cyclones) was identified as a key inhibitor. Overall, the study found that there were more factors that impeded adaptation than enabled it (though it notes possible interviewee bias), and recommends government and external agencies invest in fostering resilience and adaptive behaviour in flood-prone communities. |
| **Methodology** | This study undertook literature review, then interviews and questionnaires for the case study locations. |
| **Output** | Knowledge |
| **States (specific location)** | Queensland (Chelmer, Graceville, Tennyson, Rocklea, Brisbane, Emerald), Victoria (Donald) |
| **Sector Relevance** |  |

| Future change in ancient worlds: Indigenous adaptation in northern Australia | |
|---|---|
| **Authors (Year)** | D. Bird, J. Govan, H. Murphy, S. Hardwood, K. Haynes, D. Carson, S. Russell, D. King, E. Wensing, N. Tsakissiris, S. Larkin (2013) |
| **Status** | Draft |
| **Summary** | This report examines underlying vulnerabilities, adaptive capacity and population movements of Indigenous people within four remote northern Australian communities already exposed to extreme weather events and climate variability. Through a literature review, demographic analysis and interviews with different people in the Indigenous communities, a unique set of circumstances emerge which directly and indirectly influence each community's vulnerability and adaptive capacity as a result of their history, their environment and exposure to hazards, their relationships with stakeholders, and their understanding and expectations of climate change<br><br>Factors such as the centralisation of services in remote areas, loss of culture and connection to country, dependence on government funding, lack of monitoring, ad hoc development and land use planning and the multi-faceted issue of poverty were all found to contribute to vulnerability. However, the remoteness of these communities can also enhance adaptive capacity by creating greater levels of self-reliance. As such, emergency management and other adaptation strategies for remote communities need to be considered separately from those for other communities. |
| **Methodology** | This study utilised literature reviews, census data, spatial network analysis and case studies involving stakeholders at the three locations. |
| **Output** | Knowledge |
| **States (specific location)** | Broome, WA<br><br>Maningrida and Ngukurr, NT<br><br>Wujal Wujal, Qld |
| **Sector Relevance** |  |

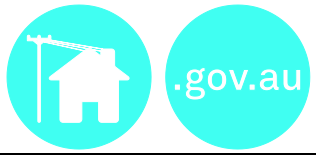
| Heat-ready: heatwave awareness, preparedness and adaptive capacity in aged care facilities in three Australian states: New South Wales, Queensland and South Australia. | |
|---|---|
| **Authors (Year)** | D.A. Black, C. Veitch, L.A. Wilson, A. Hansen (2013) |
| **Status** | Draft report |
| **Summary** | This report assessed the preparedness of aged care facilities (ACFs) in New South Wales, Queensland and South Australia to adapt and respond to heatwaves and extreme heat.<br><br>The research was conducted through computer-assisted telephone interviews with 297 ACFs, with questions to identify policies relating to extreme heat and adaptation, cooling strategies and mechanisms, staff training and education, communication procedures, knowledge of risk minimisation, and current and future infrastructure capability to deal with extreme heat.<br><br>Though the study found that heatwave policies were not routine in any state, many did have some provisions in their ACF emergency/ disaster plan; however, these were inconsistent, and generally did not take into account the full risks of extreme heat events. The project found that air-conditioning was considered the main preventative measure against heatwave-related illness in the majority of facilities, though many did not have back-up generators to cope with power outages that can occur during these events. Strategies identified to improve the adaptive capacity of aged care facilities include development of facility-specific heatwave plans, training and clinical protocols that deal with extreme heat. |
| **Methodology** | Computer-assisted telephone interviews were conducted with representatives from facilities. |
| **Output** | Knowledge |
| **States (specific location)** | New South Wales, Queensland, South Australia |
| **Sector Relevance** |  |

| Recovery from disaster: resilience, adaptability and perceptions of climate change | |
|---|---|
| **Authors (Year)** | H.J. Boon, J. Millar, J. Lake, A. Cottrell, D. King (2012) |
| **Status** | Draft report |
| **Summary** | This report assessed the resilience of people who remained in disaster-affected communities and the beliefs, behaviours and policies that encourage greater community resilience. Specifically, individuals from the bushfire-impacted Beechworth community, drought-impacted Bendigo community, flood-impacted Ingham community and cyclone-impacted Innisfail community were interviewed and surveyed to assess their resilience, with an analysis of commonalities between responses undertaken.<br><br>It was found that the safety and wellbeing of individuals through support from neighbours, friends and family and other local support networks (formal and informal) contribute to resilience, as does physical and emotional preparedness through advance warnings. The research uncovered a need for increased and more flexible support, recovery and health services for longer periods after a disaster event. |
| **Methodology** | The study team undertook literature review, interviews and surveys. |
| **Output** | Knowledge, Testing of methodology or approach, Tools or guidelines |
| **States (specific location)** | Victoria (Beechworth, Bendigo), Queensland (Ingham, Innisfail) |
| **Sector Relevance** |  |

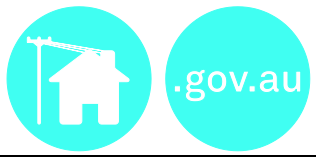
| Understanding coastal urban and peri-urban indigenous people's vulnerability and adaptive capacity to climate change | |
|---|---|
| **Authors (Year)** | D.L. Choy, P. Clarke, D. Jones, S. Serrao-Neumann, R. Hales, O. Koschade (2013) |
| **Status** | Draft report |
| **Summary** | This report examined the impacts of climate change on peri-urban and urban Indigenous communities and their capacity to adapt.<br><br>By considering the impacts of climate change on five communities, the following priority areas of concern were identified for individuals, households, businesses and institutions:<br>• Opportunities and capacity to represent Indigenous knowledge and values in state and federal government processes relating to environmental management and land use<br>• Flexibility to move or modify housing to better adapt to climate change<br>• Strategic consideration of climate change on employment opportunities and risk, particularly in natural resource–based industries<br>• Use of environmental and cultural assets to inform climate change monitoring, communicate Indigenous perspectives on environmental issues and build environmental awareness<br>• Impacts on and opportunities for the wild food network.<br><br>The report includes recommendations for ongoing engagement with Indigenous communities through increased collaboration and inclusiveness to improve Indigenous land use agreements. A proposed research framework to build a more comprehensive research agenda has also been included. This incorporates specific research needs that have been prioritised by Indigenous representatives on the project reference group. |
| **Methodology** | This study undertook a literature review. Data was collected through workshops in five case study areas and through selected interviews with Elders and other knowledgeable people. |
| **Output** | Knowledge |
| **States (specific location)** | Victoria (North Geelong, Mornington Peninsula)<br>South Australia (Adelaide Plains)<br>Queensland (Stradbroke Island, Moreton Bay, Brisbane–Ipswich) |
| **Sector Relevance** |  |

| Benefits and costs of provision of post-cyclone emergency services | |
|---|---|
| **Authors (Year)** | L. Dobes, G. Scheufele, J. Bennett (2012) |
| **Status** | Draft |
| **Summary** | This report explored whether there is a perceived net social benefit to providing accelerated post-disaster services (primary infrastructure reconnection, increased emergency and disaster services, support services, etc.) in towns affected by cyclones.<br><br>Using Cairns as a case study, this project used a Discrete Choice Experiment to focus on whether residents found the increased costs of particular services outweighed the benefits. The services used for the experiment included accommodation of pets, increased police patrols, faster resupply of fresh food, faster reconnection of utilities and the provision of a cyclone levy; with the practical logistics and costs of the services investigated.<br><br>The project found that it may not be possible or deemed financially worthwhile to deliver all services at an accelerated or increased rate in all areas. The services identified as most worthwhile in this case study were faster resupply of fresh food and faster reconnection of utilities. |
| **Output** | Knowledge |
| **Methodology** | This study used a Discrete Choice Experiment delivered through a survey to residents to identify perceived worth and benefit of services, and interviews with service providers to estimate the costs. |
| **States (specific location)** | Queensland (Cairns) |
| **Sector Relevance** |  |

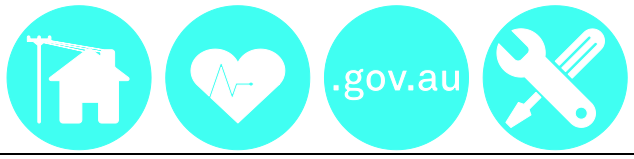
| Limits to climate change adaptation in the Great Barrier Reef: scoping ecological and social limits | |
|---|---|
| **Authors (Year)** | L.S. Evans, P. Fidelman, C. Hicks, C. Morgan, A.L. Perry, R. Tobin (2011) |
| **Status** | Final report |
| **Summary** | This report assessed climate change impacts and adaptation pathways for the Great Barrier Reef. Specifically, the report looked at climate change adaptation limits and opportunities, conflicts, compromises, synergies and collaborations between sectors that relate to the region.<br><br>Using a set of four alternative scenarios, a range of ecological and social adaptations options and limits were explored. Although a number of ecological limits were directly due to species' specific physical thresholds (such as temperature and water pH), there were also limits for many species that were resilient to these changes due to a decline of species they are dependent on, or a change in ecosystems due to key species decline. The social adaptations focused on the local tourism and the fishing industry, and identified adaptation options such as reorganisation of industry, increased business and emergency planning, improved forecasting, financial management, marketing, networking, mobility, diversification, technology and infrastructure development.<br><br>A number of limits were identified in literature and by stakeholders, though the study team contend that many of these are not absolute – that the thresholds are subjective, and therefore can be seen as opportunities if viewed through an alternate mindset. |
| **Methodology** | This study undertook literature review, stakeholder workshops and interviews. |
| **Output** | Knowledge |
| **States (specific location)** | Queensland (Great Barrier Reef) |
| **Sector Relevance** |  |

| Costs and coasts: an empirical assessment of physical and institutional climate adaptation pathways | |
|---|---|
| **Authors (Year)** | C.S. Fletcher, B.M. Taylor, A.N. Rambaldi, K. Ganegodage, B. Harman, S. Heyenga, F. Lipkin, R.R.J. McAllister (2013) |
| **Status** | Draft report |
| **Summary** | This report assessed the economic costs, benefits and equitability of inundation adaptation measures for coastal communities.<br><br>Using estimated sea level rise up to 2100 for six case study settlement typologies, the financial losses from inundation were estimated (including building damage and property devaluation), as well as the potential implications of adaptations. The distribution of these costs and benefits across the community was evaluated, as well as the ability to fund the adaptations.<br><br>A major finding of this study was an inability to fund financially justifiable adaptation options in some of the community types. The report suggests that higher level mechanisms will be needed to provide or help organise funding for some of these measures. |
| **Methodology** | Case study settlements at three LGA jurisdictions were used to come up with coastal community typologies. Economic analysis of the costs and benefits for these community typologies was undertaken. |
| **Output** | Knowledge, Testing of methodology or approach |
| **States (specific location)** | Queensland (Sunshine Coast, Cairns, Moreton Bay) |
| **Sector Relevance** |  |

| Climate change responses and adaptation pathways in Australian coastal ecosystems: synthesis report | |
|---|---|
| **Authors (Year)** | W.L. Hadwen, S.J. Capon, E. Poloczanska, W. Rochester, T. Martin, L. Bay, M. Pratchett, J. Green, B. Cook, A. Berry, A. Lalonde, S. Fahey (2011) |
| **Status** | Final report |
| **Summary** | This report is a synthesis of research on coastal ecosystems, climate impacts and risks, and management strategies, with a focus on how anthropic and ecological adaptation pathways can minimise the impacts of climate change and allow coastal ecosystems to recover.<br><br>The study undertakes a broad-scale exploration of Australian coastal processes and ecosystems, possible climate changes in the differing coastal zones, and resultant climate change impacts and hazards for the ecosystems that reside in these zones. Autonomous and managed adaptation pathways are explored, as well as possible unintended impacts on humans and ecosystems of adaptation options.<br><br>The study finds that immediate action on climate change should be taken, with the need to engage stakeholders and the community to get behind adaptation actions as key. It is suggested this is done by clearly articulating probable impacts and the goals of the adaptation plan (together with alternate options), underlining the benefits of early and effective actions, and highlighting maladaptive options and actions. |
| **Methodology** | The project team reviewed an extensive list of literature and synthesised this into end-user products. |
| **Output** | Knowledge, Tools or guidelines |
| **States (specific location)** | Northern Territory (Kakadu National Park), New South Wales (Newcastle, Hunter Estuary), Queensland (Cairns Region). |
| **Sector Relevance** |  |

| Storm tides, coastal erosion and inundation | |
|---|---|
| **Authors (Year)** | P. Helman, F. Thomalla, C. Metusela (2010) |
| **Status** | Final report |
| **Summary** | This report assessed the adaptive response to storm tides of three case study communities historically affected by extreme climatic events, examined adaptation responses and assessed vulnerability changes over the period since.<br><br>Specifically, the report focused on coastal communities in the Gold Coast, Byron Bay and Collaroy–Narrabeen, which were affected by significant storm tides in the period between the early 1950s and mid-1970s. All of these areas have experienced relative calm in the period since.<br><br>The project found that many of the lessons learned following the storm events have been lost due to a turnover in the community over time, a lack of immediate policy change and lack of community push for changes as the momentum and memories faded. Vulnerability has increased in the areas due to community and governments' 'calm weather planning' mentality, which has led to rapid development in the period since, an influx of people who did not experience the previous events, individual attitudes that storms tides experienced are related to 1-in-100 year events (so will not happen again in their lifetimes). |
| **Methodology** | This study undertook literature review and interviews. |
| **Output** | Knowledge |
| **States (specific location)** | Queensland (Gold Coast), New South Wales (Byron Bay, Collaroy–Narrabeen) |
| **Sector Relevance** |  |

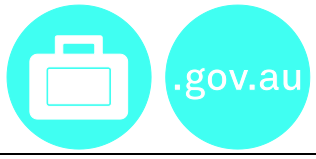
| An assessment of Australia's existing statutory frameworks, associated institutions, and policy processes: do they support or impede national adaptation planning and practice? | |
|---|---|
| **Authors (Year)** | K. Hussey, R. Price, J. Pittock, J. Livingstone, S. Dovers, D. Fisher, S. Hatfield-Dodds (2013) |
| **Status** | Draft report |
| **Summary** | This report assessed the extent that institutional arrangements support or impede adaptation, where there is a need for revisions to these processes or new institutions, and whether a strategic national policy framework has the potential to deliver these changes.<br><br>The report explores this through seven policy and framework case studies that cover factors including the potential of national and inter-governmental frameworks (including those that relate to the primary industries sector) and planning regimes to address climate adaptation, the role of the financial market in climate adaptation, informational availability, accessibility and the need for connectivity between information providers and users, and interactions between policy mechanisms. The research suggests that although it is evident that all levels of Australian government are aware of climate risk, and that the regulatory and institutional landscapes generally support adaptation planning by being dynamic and flexible, a number of policy concerns and major barriers to effective implementation still exist.<br><br>The report suggests general measures to address these barriers, which include designing clear overarching national (or nationally consistent) frameworks and guidelines; developing incentives to encourage and facilitate private sector investment in adaptation; investing in 'no regrets' adaptation options – options that are beneficial under all climate scenarios; coordinating efforts between councils to minimise administrative burden on State and Commonwealth agencies and reduce overall financial burdens; and provision of high quality and relevant climate-relevant data and information that is accessible and able to be understood by decision-makers. |
| **Methodology** | This study reviewed literature relating to seven case study framework and policy areas. |
| **Output** | Knowledge |
| **States (specific location)** | National, Victoria (Melbourne), Queensland |
| **Sector Relevance** |  |

| Learning from regional climate analogues | |
|---|---|
| **Authors (Year)** | J. Kellett, D. Ness, C. Hamilton, S. Pullen, A. Leditschke (2011) |
| **Status** | Final report |
| **Summary** | This project investigated climate change adaptation policy lessons for selected target cities through the study of analogous settlements that are currently experiencing climatic conditions similar to those predicted for the target cities.<br><br>The study examined policy documents across a range of sectors for the paired locations to extract aspects that may be viewed as a response to climate and interviewed local government and state government agencies to gain a qualitative understanding of the role of climate on policy decisions.<br><br>The project found that although there were not significant differences in policy between the target and analogue cities, or even enough potential learning opportunities to justify further studies of further pairings, some useful information was uncovered by the process. This included an apparent disconnect between upper levels of policy and on-the-ground practice due to practicalities (local conditions, lack of integration with other council activities, lack of defendable data and competing policies); differing public and government expectations; and problems with top-down land use policy being flexible enough to deal with local climate conditions. |
| **Methodology** | Policy reviews were undertaken across a range of sectors for case study cities; interviews were conducted with government agencies; and a framework for analysis was developed to assess the effectiveness of the research and to evaluate the usefulness of a second stage of research. |
| **Output** | Tools or guidelines, Testing of methodology or approach, Knowledge |
| **States (specific location)** | South Australia (Whyalla, Port Pirie, Adelaide), Queensland (Gladstone, Brisbane), Western Australia (Broome, Perth) |
| **Sector Relevance** |  |

| Learning from experience: historical case studies and climate change adaptation | |
|---|---|
| **Authors (Year)** | A.S. Kiem, D.C. Verdon-Kidd, S. Boulter, J. Palutikof (2010) |
| **Status** | Final report |
| **Summary** | This report is a summary of the historical case studies developed via the NCCARF consortium in 2010, and synthesis of the climate variability and adaptation lessons that can be learned from them. The summary included case studies on Cyclone Tracy, which struck Darwin on Christmas Day 1974; drought in rural communities, looking at the agricultural communities of Donald and Mildura, and the mining communities of broken Hill and Kalgoorlie; heatwaves that occurred in Melbourne and Adelaide in early 2009; the Queensland floods of early 2008; severe storm tides along the southern Queensland and northern New South Wales coast; and the Pasha Bulker storm that affected Newcastle in June 2007.<br><br>The summary found broad lessons from across the case studies. These included a need for all levels of government to provide frameworks of regulation and incentives to enable adaptation; recognition that solutions which address extreme, short-term events are not necessarily suitable under long-term climate change; that successful adaptation relies on establishing a clear threshold for emergency and recognising a new type of disaster; a need for communities to know how to respond appropriately to a disaster and not necessarily rely on communication capacity during the event; that transformational change (substantial alteration from existing practices) may be needed in the long term in some communities; and that the geographical, social, cultural or economic characteristics of some communities simply make them more vulnerable to a changing climate. |
| **Methodology** | This project involved a literature review and summary of case studies. |
| **Output** | Knowledge |
| **States (specific location)** | Northern Territory (Darwin), Victoria (Donald, Mildura, Melbourne), New South Wales (Broken Hill, Newcastle), South Australia (Adelaide), Queensland (Charleville, Mackay), Western Australia (Kalgoorlie) |
| **Sector Relevance** |  |

| Limits and barriers to climate change adaptation for small inland communities affected by drought | |
|---|---|
| **Authors (Year)** | A.S. Kiem, E.K. Austin (2012) |
| **Status** | Final report |
| **Summary** | This report assessed the implications of using market-based instruments (MBIs) on adaptation. Specifically, it focused on the barriers and limitations to climate change adaptation in small inland communities using water trading.<br><br>The project found that water trading has potential to deliver beneficial adaptation outcomes, although for some people and industries there may be negative impacts. Water trading will allow people with the financial capacity to purchase water greater flexibility in making decisions about their priorities for water use. However, water trading can also have adverse consequences on local communities (such as smaller agriculture operations and drinking water supply), particularly as residents may sell their water entitlements and exit the community. |
| **Methodology** | This study took a case study approach, examining water trading in the Murray–Darling Basin as an MBI for climate change adaptation. |
| **Output** | Knowledge, Testing of methodology or approach |
| **States (specific location)** | Queensland, New South Wales, Australian Capital Territory, Victoria, South Australia (Murray–Darling Basin) |
| **Sector Relevance** |  |

| Planning, building and insuring: adaptation of built environment to climate change–induced increased intensity of natural hazards | |
|---|---|
| **Authors (Year)** | D. King, J. Ginger, S. Williams, A. Cottrell, Y. Gurtner, C. Leitch, D. Henderson, N. Jayasinghe, P. Kim, K. Booth, C. Ewin, K. Innes, K. Jacobs, M. Jago-Bassingthwaighte, L. Jackson (2012) |
| **Status** | Draft report |
| **Summary** | This research explored the probable impacts of extreme and intensified climate-related events on the built environment and examined using regulatory mechanisms in climate change adaptation and response. Specifically, the regulatory mechanisms and industry best practice examined relate to land use planning, building regulation and insurance.<br><br>The elements of planning, building and insuring were first examined individually, then as a whole built-environment practice. The extent of separation and lack of information sharing between these co-dependent sectors (partly due to differences in knowledge sets, governing bodies and operational guidelines) was identified, as was the extent that they influence each other and rely on a consistent approach to be most effective. A lack of consideration of predictable extreme weather events – even without future climate change risks – was identified within all three sector policy responses. |
| **Methodology** | This project undertook literature review, stakeholder interviews and a workshop to build case studies. |
| **Output** | Knowledge |
| **States (specific location)** | Queensland (Mission Beach, Brisbane, Lockyer Valley), Tasmania |
| **Sector Relevance** |  |

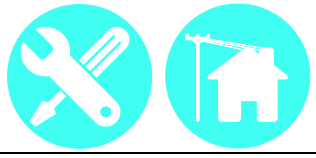
| Understanding the adaptive capacity of Australian small-to-medium enterprises (SMEs) to climate change and variability | |
|---|---|
| **Authors (Year)** | N. Kuruppu, J. Murta, P. Mukheibir, J. Chong, T. Brennan (2013) |
| **Status** | Draft report |
| **Summary** | This report investigated the adaptive capacity of small- to medium-sized enterprises (SMEs) around Australia, including the underlying factors and processes that influence SME engagement with climate adaptation, barriers and opportunities for particular sectors, and strategies for the future.<br><br>The study focused on ways that SMEs have considered and incorporated adaptation into business planning, determinants that hinder or guide adaptive capacity, and support mechanisms needed for SMEs to be viable with continued climate change.<br><br>The study observed a higher likelihood of incorporating short-term climate extremes into business planning, rather than medium- to long-term climate change. Government regulations, access to relevant climate change information and knowledge were identified as general external determinants that underpin adaptive capacity; with climate change the climate change beliefs and values of the organisation (or owner), the size of the business and its network, and extent of forward planning were identified as internal determinants. Provision of access to support mechanisms, including educational and training initiatives, case-workers and business advisors were identified as being able to be provided through modifications to current processes and networks. |
| **Methodology** | Empirical data was collected through online surveys; semi-structured interviews were conducted; five case study businesses were analysed; and stakeholder workshops were undertaken. |
| **Output** | Knowledge |
| **States (specific location)** | Queensland (Cassowary), New South Wales (Parramatta), Victoria (Marysville, Kinglake), Western Australia (south-west Western Australia) |
| **Sector Relevance** |  |

| The role of water markets in climate change adaptation | |
|---|---|
| **Authors (Year)** | A. Loch, S. Wheeler, S. Beecham, J. Edwards, H. Bjornlund, H. Shanahan (2012) |
| **Status** | Final Draft |
| **Summary** | This study investigated the relationship between the southern Murray–Darling Basin water markets and how these may be affected by anticipated future climate change impacts.<br><br>Specifically, the study investigated how water markets have been implemented in the Murray–Darling Basin and the expected climate change impacts for the southern Murray–Darling Basin and for the agricultural industry. The report then examined the financial, social and ecological impacts of market-based water reallocation and opportunities for future development to encourage positive outcomes in these areas.<br><br>The report identified predominantly positive financial and ecological outcomes from water markets, and little evidence of negative social impacts as a whole. |
| **Methodology** | This study took a literature review approach. |
| **Output** | Knowledge |
| **States (specific location)** | Queensland, New South Wales, Australian Capital Territory, Victoria, South Australia |
| **Sector Relevance** |  |

| Analysis of damage to buildings following the 2010/2011 Eastern Australian Floods | |
|---|---|
| **Authors (Year)** | M. Mason, E. Phillips, T. Okada, J. O'Brien (2012) |
| **Status** | Draft report |
| **Summary** | This report analysed the extent and mechanisms of damage that occurred during the Eastern Australia floods in late 2010 and early 2011, and what can be learned from this event. The study explored the conditions that occurred during the events in Queensland, New South Wales, Victoria and Tasmania; how buildings can be damaged during a flood event; methods of protecting from flood damage; analysis of damage data from case study areas affected during the Queensland floods; creation of a model from this data to predict flood loss and displacement; and the role of controls on planning, building design and guidance to adapt for future flooding events.<br><br>The project found that Queensland and Victoria were the most severely affected states of the Eastern Australia floods, with significant loss of life and serious financial impacts through inundation of properties. A high percentage of the properties affected in Queensland predate floodplain controls for planning or building contributing to damage – though a significant number had experienced flooding in the past. Models that were created have been proposed as useful for risk assessments for flood prone areas and rapid assessment of impacts following a flooding event; though further validation and refinement is also recommended. A number of development controls were identified for Queensland and Victoria that currently apply to floods, as well as those being developed at the moment, including the introduction of a *Flood Standard* to the Building Code of Australia, and the related *Flood Handbook* that will provide guidance and regulation on design. |
| **Methodology** | This study used a literature review and synthesis approach. |
| **Output** | Knowledge, Testing of methodology or approach, Tools or guidelines |
| **States (specific location)** | Queensland, Victoria, New South Wales, Tasmania |
| **Sector Relevance** |  |

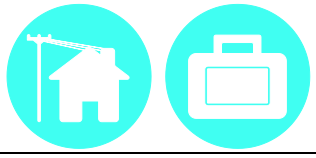
| Enhancing the resilience of seaports to a changing climate: research synthesis and implications for policy and practice | |
|---|---|
| **Authors (Year)** | D. McEvoy and J. Mullet (2013) |
| **Status** | Final report |
| **Summary** | This report examined Australian seaports under continued climate change, testing assessment methodologies, and developing tools for decision-making for port personnel. Using case studies from along Australia's Eastern seaboard, the report assessed future climate change risks to infrastructure, functional assets and the workforce, and their structural and operational vulnerabilities and resilience.<br><br>The project found that there are problems within the sector accessing and understanding climate science, climate change adaptation information and uncertainties; that there is advantage in using an integrated, participatory approach to adaptation with knowledge 'co-generation'; and that the supply and seaward sides of operations have been the most affected by current climate variability (vulnerabilities which are expected to intensify under climate change). |
| **Methodology** | This project used case studies, with literature review, interviews, and stakeholder workshops undertaken. |
| **Output** | Knowledge, Tools or guidelines |
| **States (specific location)** | Queensland (Gladstone Port), New South Wales (Sydney Port, Port Kembla) |
| **Sector Relevance** |  |

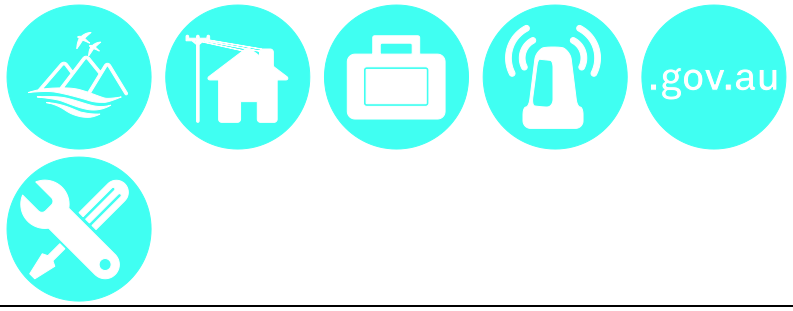
| Limits to climate change adaptation for low-lying communities in the Torres Strait | |
|---|---|
| **Authors (Year)** | K.E. McNamara, S.G. Smithers, R. Westoby, K. Parnell (2011) |
| **Status** | Final report |
| **Summary** | This report assessed how climate change is likely to affect communities living on the low-lying island of Boigu and the volcanic 'high' island of Erub, both in the Torres Strait. The research explored climate-related changes that have already occurred, and how they have affected the local community and surrounds; what livelihood assets are integral to the Islanders and how climate change may affect these assets; and the limits to adaptation for the human and natural systems on the island.<br><br>The project found that a number of climate-related changes to natural events and cycles had been observed by Islanders, which include increased heights and frequency of high tides, greater incidence of inundation events, changes to sea level, changes to rainfall and wind patterns, more frequent extreme weather events, and changes to migration and mating patterns of marine and terrestrial fauna. An extensive list of livelihood assets was identified for each island and adaptation effectiveness and limitations assessed. A number of discernible short- and medium-term limits to adaptation were identified by the Boigu people involving lack of physical capital and infrastructure – especially in relation to the low-lying nature of the island and the pace of coastal fortification. Limitations for Erub were not perceived as having the same degree of urgency or to be as numerous; however, historical failures to achieve water security for the island, and the possible lack of action on protecting low-lying areas due to the existence of higher ground were identified as key limitations. |
| **Methodology** | This study adopted a sustainable livelihoods research framework using interviews and focus groups from Boigu and Erub communities. |
| **Output** | Knowledge |
| **States (specific location)** | Queensland (Boigu, Erub) |
| **Sector Relevance** |  |

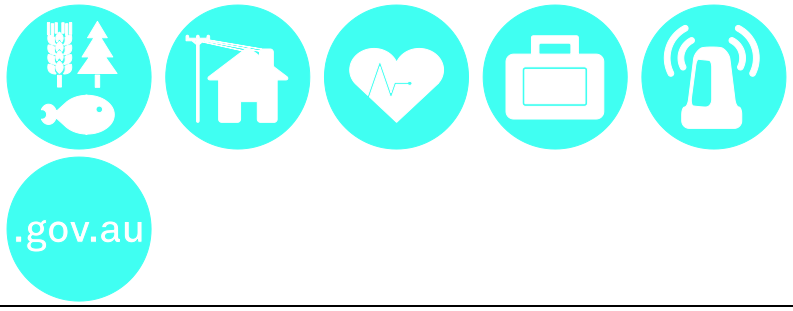
| Aboriginal responses to climate change in arid zone Australia | |
|---|---|
| **Authors (Year)** | P. Memmott, J. Reser, C. Saltmere, B. Head, J. Davidson, D. Nash, T. O'Rourke, H. Gammage, S. Suliman, A. Lowry (2013) |
| **Status** | Draft |
| **Summary** | This study investigated and documented Indigenous perceptions and knowledge of local climate change. It studied the capacity of remote Aboriginal communities located within the arid zone to respond and adapt to the effects of climate change in relation to preparedness for weather extremes, land and riverine management, housing and infrastructure and enterprise development.<br><br>A survey of perceptions of climate change in this community indicated similar responses to climate change as a national survey in relation to the reality of climate change, personal importance, level of concern and the ability to take action. However, unlike the national responses, this community felt that they knew less about climate change and were more likely to see it as a distant, global phenomenon.<br><br>Potential adaptation strategies are identified by drawing ecological assessments with Indigenous knowledge. Vulnerability is considered via research, anthropological, physiological, political and local perspectives to better consider complexity. Adaptation planning opportunities identified include negotiation of management roles, including ranger training and education about local Indigenous culture.<br><br>Indigenous people in this region have negligible control or representation in either the administration or provision of infrastructure, with the exception of Myuma. Greater participation in decision-making and the supply of infrastructure would improve adaptive capacity. This is particularly important and challenging for housing, which must be more climate- and culturally responsive. |
| **Methodology** | This study used a literature review, community survey, data review and analysis, interviews and workshops with key stakeholders. |
| **Output** | Knowledge, Tools or guidelines |
| **States (specific location)** | Upper Georgina River Basin, Qld (far north-west) |
| **Sector Relevance** |  |

| Public risk perceptions, understandings and responses to climate change and natural disasters in Australia, 2010 and 2011 | |
|---|---|
| **Authors (Year)** | J.P. Reser, G.L. Bradley, A.I. Glendon, M.C. Ellul, R. Callaghan (2012) |
| **Status** | Final report |
| **Summary** | This report synthesised the responses from the second Australian national survey on public risk perceptions and understandings of climate change. A total of 4347 respondents were surveyed between mid-2010 and mid-2011, with a broad cross-section of respondents (aged over 15) captured.<br><br>The survey incorporated questions relating to belief in climate change, trust in climate information sources (scientists, media, government), effect of climate policy on voting, and perceptions of general and specific climate risk, energy generation, and sustainability. |
| **Methodology** | A survey was undertaken, with analysis (and question content) based on literature review. |
| **Output** | Knowledge |
| **States (specific location)** | National, Queensland |
| **Sector Relevance** | .gov.au |

| Extractive resource development in a changing climate: learning the lessons from extreme weather events in Queensland, Australia | |
|---|---|
| **Authors (Year)** | V. Sharma, S. van de Graaff, B. Loechel, D.M. Franks (2013) |
| **Status** | Final report |
| **Summary** | This report explored the nature and scope of extreme weather events experienced in Central Queensland, and the impacts of these climatic extremes on the mining industry, government and dependent communities.<br><br>Specifically, the report used the Fitzroy River catchment area in the Bowen Basin coal mining region as a focus area and examined the extreme climatic events that have occurred in the area since 2000, and the impacts, responses and lessons learned from these events. The research also examined existing barriers and enablers to adaptation, drawing on past experiences, and identified possible collaborative opportunities moving forward.<br><br>Flooding and drought were the main climatic events identified, with key issues identified relating to impacts on mining company reputation due to competition over water use during droughts and quality of water discharge during floods, the difficulty of the local industry switching between the extreme 'dry' and 'wet' mindsets, and the larger-scale economic impact of these events on the state and the region. |
| **Methodology** | This study undertook literature review, interviews and workshops with stakeholders. |
| **Output** | Knowledge |
| **States (specific location)** | Queensland (Fitzroy River Catchment, Bowen Basin) |
| **Sector Relevance** |  |

| The capacities of private developers in urban climate change adaptation | |
|---|---|
| **Authors (Year)** | H. Shearer, P. Taygfeld, E. Coiacetto, J. Dodson, Z. Banhalmi-Zakar (2013) |
| **Status** | Final report |
| **Summary** | This project evaluated the institutional capabilities and readiness of the private urban development sector to effectively respond to climate change, using South East Queensland as a study area.<br><br>The project used 62 responses to an online survey, and held 21 interviews and 3 focus groups with developers and consultancies, to determine engagement of the sector, perceived climate risks and vulnerability, and factors that encouraged or deterred adaptation.<br><br>The project found that there was generally low adaptive capacity within the sector, and climate change adaptation was not considered a priority, particularly for residential and short-term projects. Larger projects and firms were considered to have a higher adaptive capacity, and were more likely to include climate change considerations in development (often mitigation), though this was often influenced by financial, insurance and governmental stakeholders or tenant demand. The overriding outlooks of respondents were that climate change is not a sufficient risk to their business to implement measures above those regulated by government, and that these regulations and insurance would be enough to mitigate risks to their businesses. |
| **Methodology** | Online surveys were conducted as part of this project, with interviews and focus groups held. |
| **Output** | Knowledge |
| **States (specific location)** | Queensland (South East Queensland) |
| **Sector Relevance** |  |

| Learning from cross-border regulatory instruments to support and promote climate change adaptation in Australia | |
|---|---|
| **Authors (Year)** | W. Steele, L. Eslami-Andargoli, F. Crick, S. Serrao-Neumann, L. Singh-Peterson, P. Dale, D. Low Choy, I. Sporne, S. Shearer, A. Lotti (2013) |
| **Status** | Draft report |
| **Summary** | This report considered lessons that can be learned from current cross-border regulatory mechanisms in Australia to enhance the efficacy of cross-border climate change adaptation practices.<br><br>Specifically, the study developed a conceptual framework to investigate cross-border arrangements between jurisdictions, using a number of case study regions (which have potential climate change issues that do not adhere to administrative boundaries) and implemented agreements, with a focus on the challenges and opportunities of these arrangements.<br><br>The project found that there are significant legal, institutional, cultural and historical challenges hindering cross-border collaboration, particularly at the state level, although local level arrangements often exist, as do an increasing number of national drivers. |
| **Methodology** | Desktop review, workshops and semi-structured interviews were employed in this study. |
| **Output** | Knowledge, Tools or guidelines |
| **States (specific location)** | Queensland (Gold Coast), New South Wales (Tweed Heads), Victoria, Australian Capital Territory (Australian Alps, Murray–Darling Basin) |
| **Sector Relevance** |  |

| Living with floods: key lessons from Australia and abroad | |
|---|---|
| **Authors (Year)** | C. Wenger, K. Hussey, J. Pittock (2012) |
| **Status** | Draft report |
| **Summary** | This report analysed inquiries and reviews into recent Australian flooding events to find common messages and key lessons. Specifically, the report focused on the findings of the Brisbane City Council's Flood Review Board Report, Queensland Floods Commission of Inquiry, Victorian Review of the 2010–11 Flood Warning and Response, and the Parliament of Victoria's Environment and Natural Resource Committee Inquiry into Flood Mitigation Infrastructure in Victoria; it synthesised the outcomes and compared the methods and findings to similar inquiries overseas. In addition, a number of experts from sectors relating to flooding were interviewed to validate and expand on the knowledge collected.<br><br>It was found that in contrast with the overseas reviews, flood reviews either mostly or totally ignored climate change impacts on flooding. Information from the reviews and interviewees pointed towards socio-institutional measures (such as education and legislation) over engineered solutions (such as use of levees) as most effective for adaptation. |
| **Methodology** | This study undertook a literature review and conducted interviews with key stakeholders (mainly to validate findings). |
| **Output** | Knowledge |
| **States (specific location)** | Victoria, Queensland |
| **Sector Relevance** |  |

# Appendix D: Excluded research (NCCARF)

### Appendix Table 4: Reports excluded due to content

| Lead author | Title | Reason for exclusion | Geographic Relevance |
|---|---|---|---|
| Barmuta | Joining the dots: integrating climate and hydrological projections with freshwater ecosystem values to develop adaptation options for conserving freshwater biodiversity | The report is focused on Tasmania, which is outside the geographical scope of this synthesis. | Tasmania |
| Byrne | Climate-resilient vegetation of multi-use landscapes: exploiting genetic variability in widespread species | This research focused on two species of eucalypt in a limited number of regions (two).The application of results to other species or locations was deemed not appropriate, and there is little to no policy relevance. | Western Australia, Victoria |
| Cockfield | Socioeconomic implications of climate change with regard to forests and forest management. Contribution of Work Package 3 to the Forest Vulnerability Assessment | The component reports I to IV were not reviewed for the synthesis, which has been informed by Synthesis and Final Report only. | National |
| Davis | Building the climate resilience of arid zone freshwater biota: identifying and prioritising processes and scales for management | The focus of this report was on technical findings related to factors influencing connectivity (population genetics, dispersal traits), so there is little policy relevance. | Queensland, South Australia, Northern Territory, Western Australia |
| Dyer | Predicting water quality and ecological responses to a changing climate: informing adaptation initiatives | The focus of this report was on technical findings, based on Bayesian network models using data from a single location, so was not considered robust enough for synthesis. | Australian Capital Territory |
| Guilding | Strata title in a world of climate change: managing greater uncertainty in forecasting and funding common property capital expenditure | The report was deemed not policy-relevant, as its focus is on private investment risk, and it is written more as a technical report for a fund manager audience. | National |
| Medlyn | Biophysical impacts of climate change on Australia's forests. Contribution of Work Package 2 to the Forest Vulnerability Assessment | The component reports I to IV were not reviewed for the synthesis, which has been informed by Synthesis and Final Report only. | National |
| Moir | Developing management strategies to mitigate increased co-extinction rates of plant-dwelling insects through global climate change | This project focused on species level assessments and the management of invertebrates under climate change, which does not appear to be a current policy priority for state governments. | Western Australia |

| Lead author | Title | Reason for exclusion | Geographic Relevance |
|---|---|---|---|
| Padgham | Agent-based simulation framework for improved understanding and enhancement of community and organisational resilience to extreme events | This report was based on the application of agent-based modelling (based on the author's main project) at one Victorian location. As there was limited testing, the report was not considered robust enough for synthesis. | Victoria |
| Padgham | Exploring the adaptive capacity of emergency management using agent-based modelling | This research was deemed more relevant to operational decision-making; although the tool may be useful to assess policies, this has not been part of the research. | Victoria |
| Reser | Public risk perceptions, understandings and responses to climate change and natural disasters in Australia and Great Britain | The follow-on research has been included (EM1101 [Reser]), which has more up-to-date results. | National |
| Sanò | Adapt between the flags – enhancing the capacity of Surf Life Saving Australia to cope with climate change and to leverage adaptation within coastal communities | The focus of this report is on asset management, life saving operations and the role of local clubs in increasing community resilience. There is mention of the role of state funding, and adaptation options have state relevance (such as retreat); however, the discussion (which is in an early stage) does not currently draw enough conclusions relevant to state/territory policy and decision-making. | Queensland, New South Wales, Tasmania |
| Foster | Analysis of institutional adaptability to redress electricity infrastructure vulnerability due to climate change | Few lessons relevant to state government policy. | National |
| Thompson | Impacts of elevated temperature and $CO_2$ on the critical processes underpinning resilience of aquatic ecosystems | The focus of this report is on technical findings related to laboratory testing and modelled future conditions. The report focuses on management options at specific locations rather than on policy. | Victoria |
| Unsworth | What about me? Factors affecting individual adaptive coping capacity across different population groups | Only 1 of the 4 identified research streams is likely to be relevant to state government adaptation policy (Stream 1 focuses on responses to carbon emissions while Streams 3 and 4 focus on specific population groups defined by employment (resource sector and hospital employees)). | National |
| Wardell-Johnson | Creating a climate for food security: the businesses, people and landscapes in food production | The report was deemed to lack policy relevance. | Queensland, Western Australia |
| Willetts | Understanding the Pacific's adaptive capacity to emergencies in the context of climate change | This report covers a topic not relevant to state and territory responsibilities. | National |

| Lead author | Title | Reason for exclusion | Geographic Relevance |
|---|---|---|---|
| Wilson | Climate change adaptation options, tools and vulnerability. Contribution of Work Package 4 to the Forest Vulnerability Assessment | The component reports I to IV were not reviewed for the synthesis, which has been informed by Synthesis and Final Report only. | National |
| Wood | Establishing the need and consultation with key stakeholders in forest policy and management under climate change. Contribution of Work Package 1 to the Forest Vulnerability Assessment | The component reports I to IV were not reviewed for the synthesis, which has been informed by Synthesis and Final Report only. | National |

## Appendix Table 5: Reports excluded due to deadline

*NCCARF research reports provided to AECOM after close of business on 14 January 2013 were also unable to be included in the synthesis due to project time constraints. In some cases, the report due date was before 14 January 2013, but the report was delayed.*

| Lead author | Title | Geographical relevance | Report due date |
|---|---|---|---|
| Abadi | EverFarm® – Design of climate-adapted perennial-based farming systems for dryland agriculture in southern Australia | New South Wales, Victoria, Western Australia | 25/01/13 |
| Barrett | Adaptive management of temperate reefs to minimise effects of climate change: developing effective approaches for ecological monitoring and predictive modelling | Tasmania | Draft 1/04/14; Final Report 30/04/14 (March–April) |
| Bax | Pre-adapting a Tasmanian coastal ecosystem to ongoing climate change through reintroduction of a locally extinct species | Tasmania | Draft 28/02/13; Final report 30/03/13 (March–April) |
| Beer | Australia's country towns 2050: What will a climate-adapted settlement pattern look like? | National | Draft: 31/12/12 |
| Burton | Urban food security, urban resilience and climate change | National | 01/10/12 |
| Caputi | Management implications of climate change effects on fisheries in Western Australia | Western Australia | Draft 30/11/13; Final report 31/12/13 (Nov–Dec) |
| Correa-Velez | Displaced twice? Investigating the impact of Queensland floods on the wellbeing and settlement of a cohort of men from refugee backgrounds living in Brisbane and Toowoomba | Queensland | Unknown |
| Crase | Leading gifted horses to water: the economics of climate adaptation in government-sponsored irrigation in Victoria | Victoria | 15/01/13 (draft) |
| Davis | Ensuring that the Australian oyster industry adapts to a changing climate: a natural resource and industry spatial information portal for knowledge action and informed adaptation frameworks | National, New South Wales | Draft 10/12/12; Final report 24/12/12 (Jan–Feb 2013) |
| Dear | Changing heat: direct impacts of temperature on health and productivity – current risks and climate change projections | National | Unknown |
| Dobes | The economics of government as insurer of last resort for climate change adaptation | National | 3/03/13 (draft) |
| Doerr | The architecture of resilient landscapes: scenario modelling to reveal best-practice design principles for climate adaptation | Victoria, Queensland, New South Wales, Australian Capital Territory | 3/02/13 (draft) |
| Frusher | A climate change adaptation blueprint for coastal regional communities | National | Draft: 01/06/13; Final report 30/06/13 |
| Fry | Reforming planning processes trial: Rockhampton 2050 | Queensland | 28/02/13 |

| Lead author | Title | Geographical relevance | Report due date |
|---|---|---|---|
| Gledhill | Identification of climate-driven species shifts and adaptation options for recreational fishers: learning general lessons from a data-rich case | Tasmania, Victoria, New South Wales, Queensland | Unknown |
| Green | Health impacts of climate change on Indigenous Australians: identifying climate thresholds to enable the development of informed adaptation strategies | Western Australia, Northern Territory, Queensland | Unknown |
| Hanna | Climate change impacts on workplace heat extremes: health risk estimates and adaptive options | National | Unknown |
| Harley | Dengue transmission under climate change in Northern Australia: linking ecological and population-based models to develop adaptive strategies | Queensland | Unknown |
| Hertzler | Will primary producers continue to adjust practices and technologies, change production systems or transform their industry – an application of real options | Western Australia, South Australia, New South Wales | 31/12/12 draft |
| Hobday | Growth opportunities and critical elements in the value chain for wild fisheries and aquaculture in a changing climate | National, Western Australia, New South Wales, Victoria, Queensland, Tasmania, South Australia | Draft 30/03/13; Final report 31/05/130 (May–June) |
| Hobday | Human adaptation options to increase resilience of conservation-dependent seabirds and marine mammals impacted by climate change | National | Draft 30/12/12; Final report 30/01/13 (Jan–Feb 13) |
| Hugo | Impact of climate change on disadvantaged groups: issues and interventions | South Australia | 3/02/13 (draft) |
| Jerry | Vulnerability of an iconic Australian finfish (Barramundi, *Lates calcarifer*) and related industries to altered climate across tropical Australia | Queensland, Northern Territory | Draft 31/10/13; Final report 31/12/13 (Nov–Dec) |
| Jones | Valuing adaptation under rapid change: anticipatory adjustments, maladaptation and transformation | National | 3/02/13 (draft) |
| Lockwood | Changing currents in marine biodiversity governance and management responding to climate change | Queensland, New South Wales, Tasmania | Draft: 14/09/13; Final report 27/09/13 (Sept–Oct) |
| Maani | Overcoming challenges for decision-making about climate change adaptation | National | 31/10/12 |
| McMichael | Climate change and rural communities: integrated study of physical and social impacts, health risks and adaptive options | National | Unknown |
| Parsons | Learning from the past, adapting in the future: identifying pathways to successful adaptation in Indigenous communities | Western Australia | 30/04/13 |
| Pecl | Preparing fisheries for climate change: identifying adaptation options for four key fisheries in south-eastern Australia | New South Wales, Victoria, Tasmania, South Australia | Draft 1/09/13; Final report 2/01/14 |

| Lead author | Title | Geographical relevance | Report due date |
|---|---|---|---|
| Pratchett | Effects of climate change on reproduction, larval development and population growth of coral trout | Queensland | Draft 1/03/13; Final report 30/06/13 (Mar–April) |
| Raybould | Beach and surf tourism and recreation in Australia: vulnerability and adaptation | New South Wales, Queensland | Draft 28/02/13; Final report 30/04/13 (Mar–April) |
| Saman | A framework for adaptation of Australian households to heat waves | New South Wales, South Australia, Queensland | Draft 11/01/13 |
| Shaw | Climate change adaptation – building community and industry knowledge | Tasmania, Western Australia, Queensland | Draft 1/02/13; Final report 1/04/13 |
| Sheaves | Estuarine and nearshore ecosystems – assessing alternative adaptive management strategies for the management of estuarine and coastal ecosystems | National | Draft 15/12/13; Final report 30/12/13 (Nov–Dec) |
| Thresher | Adapting to the effects of climate change on Australia's deep marine reserves | Tasmania, Victoria, South Australia, New South Wales | Draft: 1/06/13; Final report 1/12/13 |
| Tong | Projection of the impact of climate change on the transmission of Ross River virus disease | Queensland | Unknown |
| VanDerWal | Identification and characterisation of freshwater refugia in the face of climate change | National | 30/04/13 |
| Webb | Web-based tools for adaptation in Australia – an international and Australian review | National | 30/11/12 |
| Weir | Changes to country and culture, changes to climate: strengthening institutions for Indigenous resilience and adaptation | Queensland, Western Australia | Draft 31/12/12 |
| Welch | Management implications of climate change impacts on fisheries resources of tropical Australia | Western Australia, Northern Territory, Queensland | Draft 31/12/13; Final report 14/03/14 |
| West | Climate change adaptation: a framework for best practice in financial risk assessment; governance and disclosure | National | 31/12/12 (draft) |
| Williams | The role of refugia in ecosystem resilience and maintenance of terrestrial biodiversity in the face of global climate change | National | 30/04/13 |

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[2] *In order to incorporate the majority of NCCARF research, draft reports were considered. Many of these reports are still undergoing peer review and are not yet available publicly. Draft research incorporated into this synthesis is denoted as such in the reference (e.g. Smith 2013D).The year of the draft shows when the report was made available for incorporation into this synthesis document.*

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[3] On 30 March 2012 the Queensland Government announced machinery-of-government changes for departments. The functions of the former Department of Environment and Resource Management are now delivered by the following departments:

- Department of Environment and Heritage Protection
- Department of Natural Resources and Mines
- Department of National Parks, Recreation, Sport and Racing
- Department of Energy and Water Supply
- Department of Science, Information Technology, Innovation and the Arts.

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